INTERIM
INSTRUCTION MANUAL
MODEL PB-1C-D
VF LINE ANALYZER

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EQ GP

INTERIM

INSTRUCTION MANUAL

FOR

MODEL PB-1C-D

VF LINE ANALYZER

NOTE: Section III (Theory of Operation) and Section V (Alignment) of this manual are now in preparation. When those sections are finished, a copy of the complete manual will be forwarded.

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1110	MODEL 2A/2B LINE IMPAIRMENT GENERATOR
1130	MODEL TIG-1/E TONE AND IMPAIRMENT GENERATOR
4110	TRANSPARENT LINE GENERATOR MODEL NNE 1000/R

0-1. PB-1C-D OPERATIONAL CAUTION NOTES

a. Always check that one button in each group of pushbutton switches is depressed. There are four groups of pushbutton switches, labeled METER MODE, OSCILLATOR OUTPUT FREQUENCY, CRT MODE, and SCALE MULT. Fully depressing any non-depressed button in a group will lock that button down and release the previously depressed button in that group. However, it is possible to push two buttons in one group simultaneously, or to push one button far enough to release the previously depressed button but not far enough to lock itself, so that no button in the group remains depressed. This results in anomalous operation, and should be avoided.

b. Do not depress more than one momentary pushbutton at any time. There are five momentary pushbuttons, labeled NN FREQ, OUTPUT FREQ & LEVEL, REMOVE FILTER, ADD LF, and HARMONIC SEPARATION. Depressing more than one of the momentary pushbuttons at the same time may cause anomalous operation.

c. Hold down the momentary OUTPUT FREQ & LEVEL pushbutton to read oscillator output frequency on the frequency meter and (if either the LEVEL or NN SEP button is depressed) oscillator output level on the multi-mode meter. If the NOISE, AMPL JITTER or PHASE JITTER button is depressed, the multi-mode meter will display the oscillator output level with reversed sign. To avoid confusion which might result from the sign reversal, depress the LEVEL button to read oscillator output level on the multi-mode meter when the momentary OUTPUT FREQ & LEVEL button is used.

d. Do not attempt to read PHASE JITTER or AMPL JITTER in either the 2ND H or 3RD H CRT MODE. PHASE JITTER and AMPL JITTER can be read on the multi-mode meter only when one of the four CRT MODE VECTOR NOTCH buttons (3 TO 20, 20 TO 300, 3 TO 300, or UNFILT) is depressed but not when either the 2ND H or 3RD H CRT MODE button is depressed. If either a PHASE JITTER or an AMPL JITTER reading is attempted when either the CRT MODE 2ND H or 3RD H button is depressed, the multi-mode display will be blanked to indicate incorrect operation.

e. Do not attempt to read Second or Third Harmonic Separation on the multi-mode meter unless the 2ND H or 3RD H CRT MODE button, respectively, is depressed. Second or Third Harmonic Separation can be read on the multi-mode meter when the 2ND H or 3RD H button respectively and either the LEVEL or NN SEP button are depressed. If a harmonic separation reading is attempted when any of the CRT MODE VECTOR NOTCH buttons is depressed, the multi-mode meter will display a value near 0dB, to indicate incorrect operation.

f. Do not attempt to read any function controlled by a red button unless the red DO NOT READ light is extinguished. All of the CRT MODE buttons, the HARMONIC SEPARATION button, and three of the METER MODE buttons (NN SEP, AMPL JITTER, and PHASE JITTER) are red; the remaining buttons on the panel are black. When the DO NOT READ CRT & RED FUNCTIONS indicator is dark, the CRT and all multi-mode meter displays are valid. When the DO NOT READ CRT & RED FUNCTIONS indicator is lit, the CRT, NN SEP, AMPL JITTER, and PHASE JITTER displays are invalid, and the HARMONIC SEPARATION button is disabled.

g. Do not place the NNE switch in the ATTEN position except when the PB-1C-D is used with a Bradley Telcom NNE 1000 Series Transparent Line Generator. When the NNE switch is set to NORMAL, the SCALE CHANGE ON RED FUNCTIONS indicator is dark. When the NNE switch is set to ATTEN, the SCALE CHANGE ON RED FUNCTIONS indicator flashes, indicating that all functions controlled by red buttons (CRT MODE, NN SEP, AMPL JITTER, and PHASE JITTER) have been attenuated 14dB or by a factor of 5. When the SCALE CHANGE ON RED FUNCTIONS indicator is flashing, the audio output in the SPEAKER NOTCH MODE is reduced by the same amount.

h. Anomalous Displays. When the value of the parameter being measured by the digital multi-mode meter is above or below the specified range for that parameter, an anomalous display (e.g., multiple dashes, multiple Es, or blanking of the first two digits) may appear. Such displays should never be encountered in normal measurements because the specified measurement ranges extend well beyond worst-case values.

i. When the METER MODE NOISE button is depressed, the multi-mode meter displays the dBrnC level of the signal at the INPUT jack. The specified upper limit is 70dBrnC, but the meter will actually display up to 80 $\pm$2 dBrnC. Check readings above 78dBrnC by depressing the METER MODE LEVEL button to read the input signal level in dBm. Note that dBm equals (dBrnC -90), so that 78dBrnC = -12dBm.

SECTION I

GENERAL INFORMATION

1-1. INTRODUCTION

1-2. Scope of Manual. This manual covers theory, operation, and alignment of the PB-1C-D VF Line Analyzer, as well as analysis, identification and measurement of impairments displayed by the instrument.

1-3. The PB-1C-D VF Line Analyzer is the third generation of a series of instruments employing suppressed-tone phasor-domain CRT displays* for presenting, analyzing, identifying, and measuring impairments induced on voice-frequency signals by the facilities through which those signals are transmitted. In addition to the phasor-domain CRT display, which was employed in the earlier models PB-1 and PB-1C, the PB-1C-D has an instantaneous-level bar display, a digital frequency display, and a digital multi-mode display; and selection of all functions, modes, and scale factors is facilitated by pushbutton switches. The features of the PB-1C-D are listed in Par. 1-11, and its capabilities are listed in Par. 1-12ff.

1-4. NOTES ON THE PB-1C-D CRT PHASOR-DOMAIN DISPLAY

1-5. The PB-1C-D CRT display is not designed for making tariff measurements, but for troubleshooting facilities. Within minutes experienced users can:

a. Clear facilities in cases of invalid complaints;

b. Identify problems in cases of valid complaints;

c. Identify and measure impairments for facility maintenance personnel concerned with clearing troubles;

d. Make go/no-go determinations of facilities relative to modem requirements for personnel concerned with data transmission.

1-6. The PB-1C-D CRT displays impairments induced by the facility on a test tone, in real time as they actually occur, for visual demodulation by the eye of the operator. Impairments are thereby delineated from each other with a resolution which is unique, permitting meaningful examination of all impairments simultaneously on one display. The PB-1C-D thus not only provides results extremely quickly, but it is the only existing instrument which can positively 'clear' a facility from suspicion of all impairments (including those which have been defined but are not measured by conventional test equipment, as well as those which have not been defined and which either confuse, or are ignored by, conventional test equipment), because its examination of impairments is not limited by a set of rules for detection and time averaging as is required to produce a numerical display. Thus the instrument does not become obsolete from time to time as new impairments are discovered or rules for their detection are changed.

1-7. A most significant aspect of the PB-1C-D suppressed-tone phasor-domain CRT technique is illuminated by the question, "What is being measured?" This is usually asked when the PB-1C-D is monitoring a quiet line, because nothing much appears on the CRT display. The answer is, "Everything", i.e., all impairments are being measured. The absence of activity denotes a highly desirable condition because, since the CRT display shows all impairments, it indicates not only what impairments are present, but what impairments are not present. Usually one or two impairments will predominate, depending upon the type of facility, and their magnitude can be measured. Of no less importance is the information, implicit in the display, that all other impairments are negligible.

1-8. The PB-1C-D CRT display examines a facility in the same real-time way that modems use that facility, and permits direct comparison of facility performance with modem

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* U.S. Patents, 3814868, 3906173, 3927281, 4021625, and 4061892. Other patents pending.

requirements. The instrument provides go/no-go screening capability for the relatively unskilled, and deep diagnostic information for the more sophisticated; users of the PB-1C-D, at all levels, develop insight into the nature of impairments.

1-9. The phasor-domain technique has proven particularly useful in PCM and FDM carrier maintenance as a result of its ability to identify the 'mystery problems' which other instruments do not see, such as time variation of harmonic distortion, time variation of phase intercept distortion, narrow modulation hits, slow hits, harmonic hits, aliasing and compander problems, as well as others not yet identified. Digital displays, whether on conventional instruments or on the PB-1C-D, rely on time averaging, which masks any time-varying component at frequencies above a fraction of a hertz. Data sets making a thousand or more decisions per second respond to instantaneous (peak) impairments; thus, data-inimical harmonic distortion impairments may exist on PCM and FDM facilities which are not detected by conventional harmonic and four-tone nonlinear-distortion measurements, or by conventional notched-noise measurements.

1-10. NOTE ON THE PB-1C-D DIGITAL DISPLAYS

In addition to the non-tariff measurements (described in Par. 1-5 through 1-9) which are performed by the CRT display of the PB-1C-D, the digital displays can perform the following tariffed measurements; gain, noise, notched noise, phase jitter, and harmonic distortion.

1-11. FEATURES OF THE PB-1C-D

a. Suppressed-Tone Phasor-Domain CRT Analog Display with pushbutton selection of Four Vector Notch Modes, Two Harmonic Modes, and Five Sensitivity Ranges.

b. Digital Multi-Mode Meter with pushbutton selection of Input Signal Level, Noise Level, Notched Noise Separation, Second Harmonic Separation, Third Harmonic Separation, Phase Jitter, Amplitude Jitter, and Test-Tone Oscillator Output Level.

c. Digital Frequency Meter with pushbutton selection of Input Signal Frequency, Test-Tone Oscillator Output Frequency, and Frequency of any Predominant Notched-Noise Component, e.g., Single-Frequency Interference (SFI), harmonic of test tone, or power-line pickup.

d. Instant-Reading Level Meter for Input Signal Level (range -42 to +9dBm), responds to bursts as short as 20 milliseconds, such as are encountered in polled multi-point data communications networks.

e. Internal Test-Tone Oscillator with adjustable output level (range -40 to +8dBm) and pushbutton selection of four fixed frequencies (1004Hz, 1004+2008Hz, 2008Hz, and 2713Hz) as well as one variable frequency (range 200 to 5000Hz).

f. Acoustic Outputs at adjustable volume: Input Signal or Notched Noise (Input Signal minus Tone).

g. Electrical Outputs for driving external recorders and/or Bradley Telcom 75 L/PA Printing Hit Counters.

h. Remote Test Facilities for use with remote Bradley Telcom NNE Series Transparent Line Generators: front panel controls provide tone commands for operation of remote NNEs, and scale-factor changes of all displays for direct readout of impairments relayed by remote NNEs; rear connector provides for operation with external Bradley Telcom NNE Sequencer which makes operation of remote NNEs completely automatic.

1-12. CAPABILITIES OF THE PB-1C-D

1-13. The Suppressed-Tone Phasor-Domain CRT Display has the following capabilities:

a. Troubleshoots Transmission Facilities in One Pass, immediately disproving invalid complaints or identifying causes of valid complaints.

b. Enables Comprehensive Diagnosis by Detecting and Displaying All Impairments, including types ignored by other instruments. Tracks tone component of input signal, notches out tone, and displays simultaneously in real time and true phase all the impairments that constitute the remaining 'notched noise', with those impairments meaningfully classified on a calibrated CRT graticule.

c. Makes Go/No-Go Determination of Lines for Compatibility With Modems: Permits quantitative inspection of total in-phase and quadrature uncertainties caused by channel impairments.

d. Analyzes Complex Phenomena: Separates, Classifies, and Identifies each type of Impairment, and Measures Magnitude, Sense or Direction, and Duration. Distinguishes, among Impulse Hits, Phase Hits, and Gain Hits. Distinguishes between Phase Jitter and Amplitude Jitter. Detects and measures phase and amplitude jitter outside the bandpass of other instruments, including low-frequency jitter down to 1Hz, and high-frequency jitter.

e. Identifies and Measures Test-Tone Parameters: Level, Frequency, Frequency Shift, Frequency Hits.

f. Identifies and Measures Tone-Correlated Amplitude Impairments: Amplitude Jitter, Amplitude Modulation, Gain Hits, Gain Steps, Dropouts, Fast Dropouts, Noisy Dropouts; detects Gain Hits too short or too slow to be detected by conventional Hit Counters; indicates Gain Hit duration and direction.

g. Identifies and Measures Tone-Correlated Phase Impairments: Phase Jitter, Phase Modulation, Phase Hits, Phase Steps; detects Phase Hits too short or too slow to be detected by conventional Hit Counters; indicates Phase Hit duration and direction.

h. Identifies and Measures Non-Correlated Impairments: Notched Noise, Impulse Noise, Single-Frequency Interference.

i. Identifies and Measures Distortion: Second Harmonic Distortion, Third Harmonic Distortion, Time-Varying Phase-Intercept Distortion. Continuous variation of Phase-Intercept Distortion corresponds to frequency translation. Rapid variation of Phase-Intercept Distortion causes data errors. Brief periods of rapid variation in Phase Intercept Distortion cause phase hits too slow to be seen by conventional hit counters, but cause frequency shifts large enough to confuse modems.

j. Identifies The Location of Harmonic Distortion Sources with respect to (i.e., before or after) any frequency translation which may occur on a channel.

k. Identifies PCM Impairments: Quantizing Disturbances, Foldback Products, Compandor Mistracking, Timing Breakup.

l. Identifies Transmission Facilities, such as L, N, and T carrier, and copper pair, by their characteristic visual and acoustic 'signatures'.

m. Identifies and Measures Distant Impairments: i.e., between remote points, as well as between local and remote points, when used with NNE Transparent Line Generators placed at the remote points.

1-14. The Digital Multi-Mode Meter has the following capabilities:

a. Measures input signal levels from -40 to +9.9dBm, in the voice band, using average detection.

b. Measures input signal and background noise levels from 20 to 70dBrnC (-70 to -20dBm) over the voice band, with and without C-Message weighting, using quasi-RMS detection.

c. Measures notched noise separation from -50 to 0dB over the voice band, with and without C-Message weighting, using quasi-RMS detection.

d. Measures amplitude jitter from 0 to 30% over the 20 to 300Hz band or the 3 to 300Hz band.

e. Measures phase jitter from 0 to 30° over the 20 to 300Hz band or the 3 to 300Hz band.

f. Measures output level of the internal test oscillator, over its -40 to +8dBm amplitude range and 200 to 5000Hz frequency range.

g. Measures second harmonic separation from -50 to 0dB, for any test tone in the 930 to 1030Hz frequency range.

h. Measures third harmonic separation from -50 to 0dB, for any test tone in the 930 to 1030Hz frequency range.

1-15. The Digital Frequency Meter has the following capabilities:

a. Measures the frequency of any input tone in the voice band.

b. Measures the frequency of any predominant notched noise component, e.g., single frequency interference, second or third harmonic of test tone, or power-line pickup.

c. Measures the frequency of the internal test-tone oscillator.

1-16. The Instant-Reading Level Meter is an 18-bar LED display which presents the instantaneous level of the input signal, from -42 to +9dBm, even for bursts as short as 20 milliseconds.

1-17. The Loudspeaker presents the following acoustic outputs:

a. The total input;

b. The notched noise in the input (i.e., total input minus tone); this notched noise audio output increases the diagnostic capability of the instrument by permitting auditory and visual correlation of impairments. It is particularly useful for distinguishing correlated impairments (e.g., phase and gain hits) from uncorrelated impairments (e.g., impulse hits) which have different acoustic signatures.

1-18. NOTES ON MEASUREMENTS OF IMPAIRMENTS

1-19. Properties Versus Impairments. There is a fundamental distinction between impairments of transmission facilities (which are measured by the PB-1C-D) and properties of transmission facilities, as follows:

a. The properties of a transmission facility are its linear steady-state characteristics including Gain, Amplitude Distortion (i.e., variation of gain with frequency), Delay Distortion, and Return Loss. Properties are not time-dependent. They can be completely characterized or described by sets of numbers or plotted curves (e.g., gain versus frequency) and can thus be compensated for as in adaptively equalized modems. Properties other than continuity or gain have therefore decreased in importance as causes of data-transmission problems.

b. The impairments of a transmission facility are all of its attributes, other than the properties, which cause degradation of signals. Impairments are complex and time-variable; they cannot be fully characterized by sets of numbers or plotted curves, and cannot be compensated for by circuitry. Impairments include Noise, Hits, Jitter, Distortion, and Phase-Intercept Distortion. Each type of impairment has numerous sub-classifications.

1-20. Definitions of Impairments.

a. Tone Impairments

1. Frequency Hits are rapid changes in the frequency of the received test tone which may be followed by return to the original frequency.

2. Frequency Shift is a steady-state change in the frequency of each component of the signal passing through the facility.

b. Tone-Correlated Amplitude Impairments

1. Pure Amplitude Modulation of the test tone. This impairment is virtually non-existent on telephone facilities.

2. Amplitude Jitter includes the combined effects on the amplitude of the received tone caused by pure amplitude modulation and by additive, uncorrelated impairments such as noise and single-frequency interference.

3. Gain Hits are momentary changes in amplitude that return to approximately the original value. A positive gain hit is an increase in amplitude followed by a decrease to approximately the original value; a negative gain hit is a decrease in amplitude followed by an increase to approximately the original value. Minimum hit duration for a gain hit to be counted on a conventional hit counter is 4 milliseconds. Many gain hits occur which are shorter than 4 milliseconds.

4. Dropouts are negative gain hits of at least 12dB which persist for at least 4 milliseconds.

5. Gain Steps are rapid changes in amplitude that do not return to the original value.

c. Tone-Correlated Phase Impairments

1. Pure Phase Modulation is angular modulation of the test tone.

2. Phase Jitter includes the combined effects on the phase of the received tone caused by pure angle modulation and by additive, uncorrelated impairments such as noise and single-frequency interference.

3. Phase Hits are momentary changes in phase that return to approximately the original value. Minimum hit duration must be 4 milliseconds for a phase hit to be counted on a conventional hit counter. Many phase hits occur which are shorter than 4 milliseconds.

4. Phase Steps are rapid changes in phase that do not return to the original value.

d. Non-Correlated Impairments

1. Background Noise

2. Single-Frequency Interference includes undesired spurious steady tones, but does not include phenomena such as multifrequency tone bursts that may result from crosstalk or multifrequency signaling on other channels.

3. Impulse Noise is a momentary component of the received signal noise that exceeds rms background noise level in a given frequency band by 12dB or more.

e. Distortion

1. 2nd Harmonic Distortion: single tone at twice the test-tone frequency.

2. 3rd Harmonic Distortion: single tone at three times the test-tone frequency.

3. Phase Intercept Distortion

f. PCM Impairments

1. Quantizing Disturbances

2. Timing Jitter

3. Aliasing or Foldback Products

4. Compandor Mistracking

5. Loss of Frame

1-21. Notched Noise Measurements of Impairments.

a. Transmission facilities carrying signals between data sets induce on those signals impairments that may cause the data sets to make errors when receiving those signals. It is therefore necessary to evaluate the transmission facilities for such error-causing impairments. Since data sets make decisions in the presence of signals, the transmission facilities must be evaluated while carrying signals. In the absence of a signal the only impairments generated in a facility are additive, e.g., background noise, impulse noise, crosstalk, etc. A signal offers the facility something to modulate, jitter, quantize, or distort, and thus on which to induce impairments (e.g., phase hits, gain hits, phase jitter, amplitude jitter, harmonic distortion, nonlinear distortion, quantizing noise, timing jitter, aliasing or foldback products, frequency translation, etc.) which are absent in the absence of a signal. Therefore, to meaningfully test a facility for data transmission capability a signal must be sent through it, and the received signal at the other end must be examined for impairments induced on that signal by the facility.

b. The probing signal for testing facilities is generally a nominal 1000Hz (often actually 1004 or 1010Hz) sinusoidal tone. Test-tone sources used in notched-noise measurements must have pure and stable outputs without noise, harmonics, phase jitter, or amplitude jitter, because such impairments of the original tone at the transmit end are indistinguishable at the receive end from impairments induced on the tone by the facility. Impairments of the original tone will therefore increase the measured values of impairments ascribed to the facility. For this reason the test-tone oscillators in the PB-1C-D as well as in all other Bradley Telcom instrumentation containing tone sources (PB Series Oscillators, NNE Series Transparent Line Generators, TTL Series Touch-Tone Addressable Loopback Transponders, etc.) are designed to provide outputs of extremely high quality.

c. When a sinusoidal test tone is transmitted over a voiceband facility, the signal received at the other end of the facility contains a steady-state (or quiet) tone corresponding to the test tone, plus all impairments induced on the tone by the facility, including tone-correlated impairments (AM and PM; quantizing noise; harmonics; and hits, steps, and dropouts) as well as non-correlated impairments (SFI, noise, and power-frequency pickup). Since the impairments in the received signal are generally much smaller in magnitude than the test tone, it is difficult to measure those impairments in the presence of the tone, which tends to obscure them. Therefore, in notched-noise measurements, the test tone is removed from the received signal, and the remainder of the signal (called the 'notched noise', because the tone is usually removed with a notch filter) is examined. The notched noise contains all of the impairments that were induced on the test tone by the facility, as well as those additive components which exist whether or not a signal or test tone is present, including complete information concerning the magnitude, sense or direction, duration, and phase of each impairment. All non-real-time methods of examining notched noise lose this information, because such methods employ time-averaging. Only the phasor-domain method (as exemplified in the PB-1C-D) preserves this information, because it employs instantaneous detection that permits real-time display of each impairment with its exact phase and amplitude relative to the tone.

1-22. SUPPRESSED-TONE PHASOR-DOMAIN ANALYSIS OF NOTCHED NOISE. The suppressed-tone phasor-domain method (1) tracks the frequency and (2) normalizes the amplitude of the quiet tone in the received signal; (3) eliminates the tone from the received signal, leaving only normalized notched noise; (4) resolves the normalized notched noise into in-phase and quadrature components; and (5) displays them on a cathode-ray tube so that they can be separately identified and measured by means of calibrated scales on the CRT graticule.

a. Suppressed-tone phasor-domain instrumentation accomplishes the foregoing by means of two high-gain closed loops, an Automatic Gain Control (AGC) loop and a

Notch Phase-Lock Loop (NPLL), which are interconnected to operate as a narrow-band notch filter that automatically tracks and suppresses the steady-state or quiet-tone component of a received signal.

b. The NPLL tracks the frequency of the quiet tone and generates two orthogonal reference tones; one in phase with the quiet tone, and one in quadrature with the quiet tone.

c. The AGC loop tracks the level of the quiet tone and normalizes the received signal by amplifying the quiet tone to the same amplitude as that of the in-phase reference tone. Since the in-phase reference tone is of the same amplitude and phase as the quiet tone, it is equivalent to the quiet tone, and may be subtracted from the normalized received signal, leaving normalized notched noise, 'NNN' (i.e., normalized received signal minus quiet tone) containing only the normalized impairments. This is equivalent to eliminating the quiet tone by means of an extremely narrow notch filter, but has the advantage that it automatically follows or tracks variations of the quiet tone.

d. The normalized notched noise is resolved into in-phase and quadrature components that are fed to the vertical and horizontal deflection amplifiers, respectively, of a cathode-ray tube. Since the notched noise is normalized, the vertical and horizontal deflections can be measured against the calibrated scales of a graticule located in front of the CRT screen.

1-23. SIMPLIFIED BLOCK DIAGRAM OF PB-1C-D PHASOR DOMAIN CIRCUITS (Figure 1-1)

1-24. The simplified block diagram of Figure 1-1 shows how the suppressed-tone phasor domain method is implemented by means of two interconnected loops, the Automatic Gain-Control (AGC) loop and the Notch Phase-Lock Loop (NPLL).

a. The received signal, comprising the quiet tone (V_r cos wt) and the accompanying impairments induced by the facility, is fed to the AGC Amplifier, which amplifies the received signal to the level at which the quiet tone is equal to the in-phase reference tone (V_{ref} cos wt) from the NPLL. The quiet tone and its impairments, which are thus also normalized in amplitude, are fed to the (+) input of the Difference Amplifier, as well as to the NPLL.

b. The NPLL locks to the quiet tone (V_r cos wt) in the normalized received signal and generates two synchronous reference tones; a reference tone (V_{ref} cos wt) in phase with the quiet tone, and a reference tone (V_{ref} sin wt) in quadrature with the quiet tone. The in-phase reference tone (V_{ref} cos wt) is fed to the (-) input of the Difference Amplifier and also to one input of the AGC Controller; the quadrature reference tone (V_{ref} sin wt) is fed to the Display Phase-Lock Loop (DPLL).

c. Since the (+) input to the Difference Amplifier is the normalized signal (V_r cos wt + impairments), and the (-) input is the reference tone (V_{ref} cos wt), the output of the Difference Amplifier will be the normalized signal minus the quiet tone, or the normalized impairments alone. Impairments remaining after the quiet tone component of the received signal is removed, suppressed, or 'notched' from the signal, are conventionally called 'notched noise'. Since the quiet tone is notched from the normalized received signal, the remaining impairments are referred to as 'normalized notched noise', (NNN).

1-25. The NNN voltage from the Difference Amplifier is fed to the AGC Multiplier where it is multiplied by the in-phase reference tone (V_{ref} cos wt) from the NPLL to measure that component of NNN which is in phase with the quiet tone. This is the quantity the average value of which is to be reduced to zero by the AGC Amplifier in order to leave only NNN at the Difference Amplifier output.

1-26. The quadrature output (V_{ref} sin wt) of the NPLL is used to synchronize the Display Phase-Lock Loop (DPLL). Depending on the setting of the CRT MODE buttons, the DPLL is commanded to phase-lock to the tone (when any one of the four VECTOR NOTCH buttons is depressed), to the second harmonic of the tone (when 2ND H is depressed) or to the third harmonic of the tone (when 3RD H is depressed). If the DPLL is locked to the tone, its outputs are V_{ref} cos wt and V_{ref} sin wt; if it is

locked to the second harmonic of the tone, its outputs are V_{ref} cos 2wt and V_{ref} sin 2wt; and if it is locked to the third harmonic, its outputs are V_{ref} cos 3wt and V_{ref} sin 3wt. The cosine (in-phase) output of the DPLL is fed to one input of the Cosine Multiplier and the sine (quadrature) output of the DPLL is fed to one input of the Sine Multiplier. The normalized notched noise (NNN) output of the Difference Amplifier is fed to the other input of each multiplier.

1-27. The outputs of the Cosine and Sine Multipliers are (in any one of the four VECTOR NOTCH modes) NNN cos wt and NNN sin wt, or (in the 2ND H mode) NNN cos 2wt and NNN sin 2wt, or (in the 3RD H mode) NNN cos 3wt and NNN sin 3wt. In the 3 TO 20, 20 TO 300, 3 TO 300, or UNFILTered VECTOR NOTCH modes, the Cosine and Sine Multiplier outputs NNN cos wt and NNN sin wt are fed through filters of the designated bandwidths to the CRT vertical and horizontal deflection circuits, respectively. (The UNFILTered bandwidth is that of the entire voice-frequency band). In the 2ND H or 3RD H mode, the Cosine and Sine Multiplier outputs NNN cos 2wt and NNN sin 2wt or NNN cos 3wt and NNN sin 3wt are fed through narrowband 0-3Hz filters to the CRT vertical and horizontal deflection circuits.

1-28. The time constants of the AGC Loop and of the Notch and Display Phase-Lock Loops are chosen so that the loops operate rapidly enough to recover from transients within the 1/8 second dead-zone interval of hit counters, but do not operate so rapidly that they mask hits, steps, or other transients.

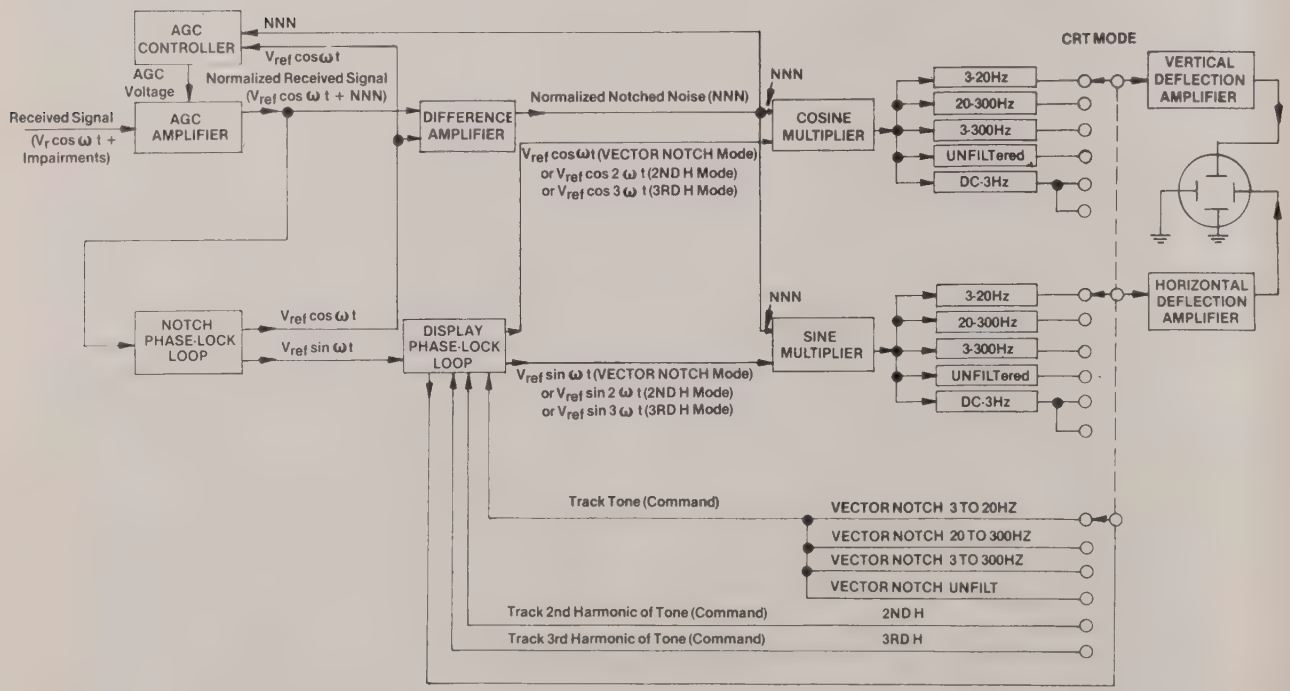

Figure 1-1. Simplified Block Diagram PB-1C-D Phasor-Domain Circuits

SECTION II

DESCRIPTION OF PB-1C-D V-F LINE ANALYZER

2-1. EXTERNAL DESCRIPTION (See Figure 2-1).

2-2. The PB-1C-D is contained in a portable case 17-1/2" wide, 5-1/4" high, and 12-1/2" deep, exclusive of panel controls and handles. A bail or tilt stand on the underside of the case permits the instrument to be tilted up for ease of viewing the displays and operating the controls, and bumpers at the rear of the case permit the unit to be stood with panel up for use in the narrow aisles between equipment racks. Available options include a carrying case, and an adapter kit for mounting the PB-1C-D in a 19" rack (see Par. 2-18). The feet and bail assembly are outside the 5-1/4" height and must be removed to mount the PB-1C-D in a 5-1/4" high panel slot.

2-3. FRONT OF INSTRUMENT (See Figure 2-2).

2-4. The following items are located on the front panel:

a. The screen, graticule, and bezel of a cathode-ray tube. In a column at the left of the CRT are a DO NOT READ CRT & RED FUNCTIONS indicator and three controls (INTENSITY, FOCUS, and SCALE ILLUMination), and at the right of the CRT are a column of six interlocked red CRT MODE pushbuttons, a column of five interlocked black SCALE MULTiplier pushbuttons, and a loudspeaker.

b. At the left of the panel are, from top to bottom: a digital frequency display and two related momentary pushbuttons labeled NN FREQuency and OUTPUT FREQuency & LEVEL; a digital multi-mode display and related pushbuttons (a row of five interlocked METER MODE pushbuttons, of which the three at the right are red, and the two at the left are black; and two black momentary pushbuttons labeled REMOVE FILTER and ADD LF); and controls for an internal test-tone oscillator (OUTPUT LEVEL potentiometer; a row of five interlocked OSCILLATOR OUTPUT FRQUENCY pushbuttons, and a 200 to 5000Hz potentiometer).

c. Along the bottom of the panel are, from left to right: a POWER toggle switch and a fusepost; a SCALE CHANGE ON RED FUNCTIONS indicator and an NNE toggle switch (for testing at remote points by means of external NNE-1000 Transparent Line Generators); fast INPUT LEVEL bar display meter; five 310 jacks labeled OUTPUT, INTERCONNECT A, INTERCONNECT B, XY OUT, and XY IN; a red HARMONIC SEPARATION momentary pushbutton, a 310 jack labeled INPUT; a 600Ω/BRIDGE toggle switch and a HOLD COIL toggle switch; a SINGLE AXIS toggle switch; a SPEAKER VOLUME control; and a SPEAKER MODE toggle switch.

d. Note the following:

1. Depressing more than one of the five momentary pushbuttons (NN FREQ, OUTPUT FREQ & LEVEL, REMOVE FILTER, ADD LF, and HARMONIC SEPARATION) at the same time may cause erroneous or invalid readings.

2. Fully depressing any button in any of the interlocked groups (METER MODE, OSCILLATOR OUTPUT FREQUENCY, CRT MODE, and SCALE MULT) will lock that button down and release the previously depressed button in that group. Although it is impossible for more than one button in each group to remain down, it is possible to partially depress any other button in that group so that it releases the previously depressed button without remaining down itself. Thus all buttons in the group can remain up, causing anomalous operation and erroneous or invalid displays.

2-5. SIDE AND REAR OF INSTRUMENT

2-6. The following items are located at the side and rear of the instrument:

a. A three-pront recessed-male ac power receptacle is located on the left side.

b. A 25-pin EIA connector is located at the rear. This permits rear connections from most of the front-panel jacks to a remote patch panel.

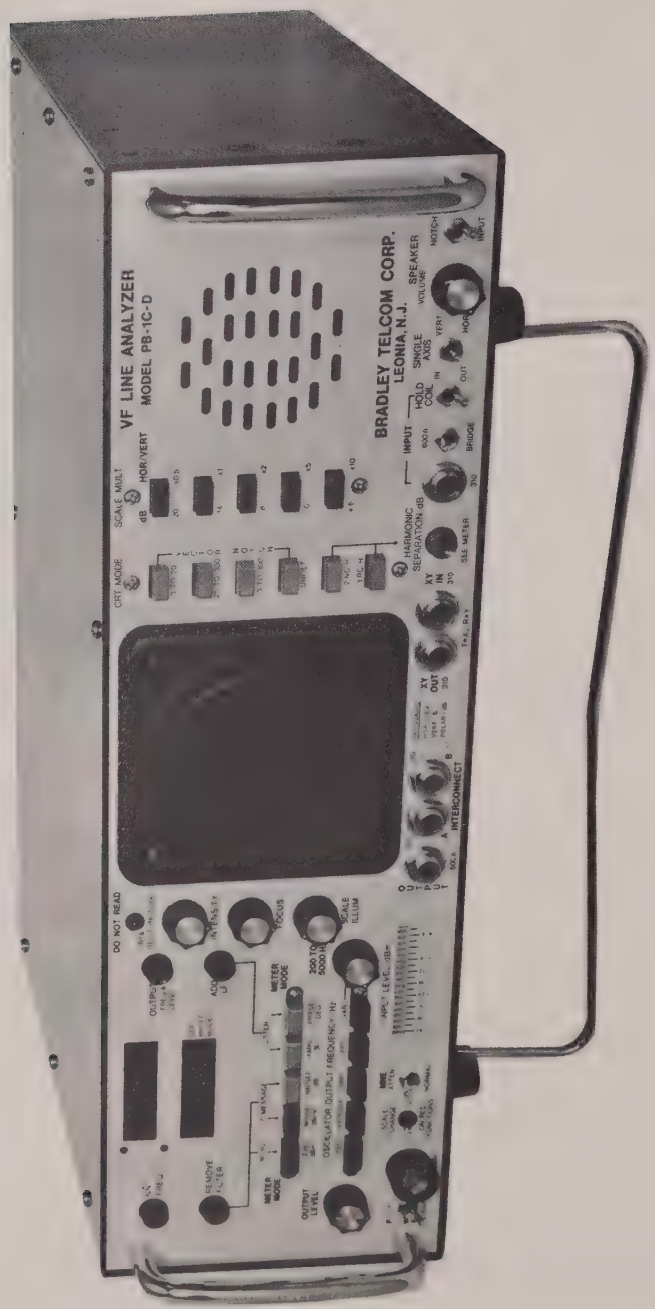

Figure 2-1. Model PB-1C-D Voice-Frequency Line Analyzer

MODEL PB-1C-D CONTROLS

- DIGITAL MULTI-MODE METER displays quantities selected by **METER MODE** buttons and other buttons as described below:
- Input Signal **LEVEL** (range −40 to +9.9dBm), average-detected. Depress **REMOVE FILTER** button to remove 60Hz rejection filter.
- **NOISE** Level (range 20 to 70dBrnC), C-Message weighted, quasi-RMS detected. Depress **REMOVE FILTER** button to remove C-Message weighting.
- Notched-Noise Separation, **NN SEP** (range −50 to 0dB), C-Message weighted, quasi-RMS detected. Depress **REMOVE FILTER** button to remove C Message weighting.
- **AMPL JITTER** (range 0 to 30%) in 20 to 300Hz band, peak-detected, in any **VECTOR NOTCH CRT MODE.** Depress **ADD LF** button for 3 to 300Hz.
- **PHASE JITTER** (range 0 to 30°) in 20 to 300Hz band, peak-detected, in any **VECTOR NOTCH CRT MODE.** Depress **ADD LF** button for 3 to 300Hz.
- Oscillator Output level (range −40.0 to +8dBm), when **OUTPUT FREQ & LEVEL** button is depressed, regardless of which **METER MODE** button is depressed.
- Second Harmonic Separation (range −50 to 0dB), when **2ND H CRT MODE** and **HARMONIC SEPARATION** buttons are depressed, and either **LEVEL** or **NN SEP METER MODE** button is depressed.
- Third Harmonic Separation (range −50 to 0dB), when **3RD H CRT MODE** and **HARMONIC SEPARATION** buttons are depressed, and either **LEVEL** or **NN SEP METER MODE** button is depressed.

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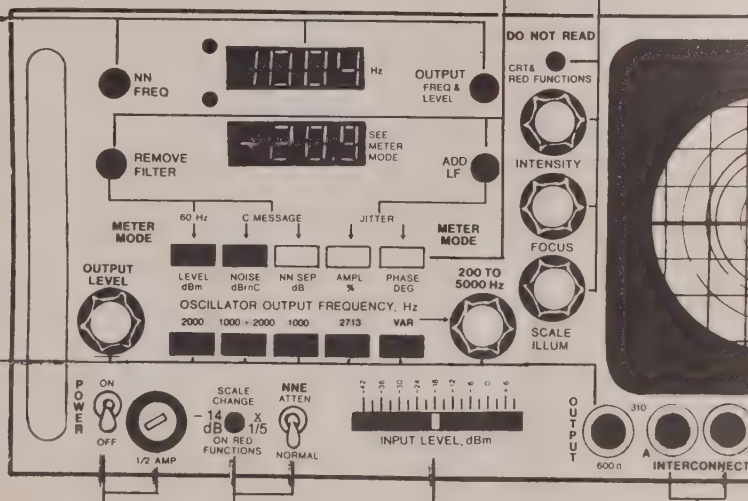
- DIGITAL FREQUENCY METER displays frequencies as follows:
- Input Signal Frequency (range 40 to 5000Hz) when **NN FREQ** and **OUTPUT FREQ & LEVEL** buttons are not depressed
- Frequency of any Predominant Notched Noise Component, e.g., SFI, 2nd H, 3rd H or power-frequency pickup, when **NN FREQ** button is depressed.
- Oscillator Output Frequency (range 200 to 5000Hz) when **OUTPUT FREQ & LEVEL** button is depressed



- Oscillator **OUTPUT LEVEL** control. Depress **OUTPUT FREQ & LEVEL** button to read oscillator output level on Multi-Mode Meter.
- **OSCILLATOR OUTPUT FREQUENCY** buttons select **2000Hz, 1000+2000Hz, 1000Hz, 2713Hz,** and **VAR**iable output frequency.
- **200 to 5000Hz** control is operative when **VAR** button is depressed. Depress **OUTPUT FREQ & LEVEL** button to read oscillator output frequency on Frequency Meter.
- Oscillator 600Ω **OUTPUT** jack

- Fast **INPUT LEVEL** Bar Display (range −42 to +9dBm) responds to input signal bursts as short as 20 milliseconds, for monitoring polled multi-point data communications networks.

- **POWER ON/OFF** switch and fuse.

- **NNE ATTEN/NORMAL** switch. Usually set to **NORMAL;** set to **ATTEN** for notched-noise-enhanced input from remote NNE-1000 Transparent Line Generator.
- **SCALE CHANGE ON RED FUNCTIONS** indicator flashes when **NNE** switch is set to **ATTEN.**

- **INTERCONNECT A** and **B** jacks provide outputs for other instruments, such as the Bradley Telcom 75L/PA Printing Hit Counter. **INTERCONNECT A** Tip = Phase-Lock Local Oscillator; INTERCONNECT A Ring = Normalized Input; **INTERCONNECT B** Tip = Normalized Notched Noise; INTERCONNECT B Ring = Input Repeat.

DISPLAYS AND INDICATORS

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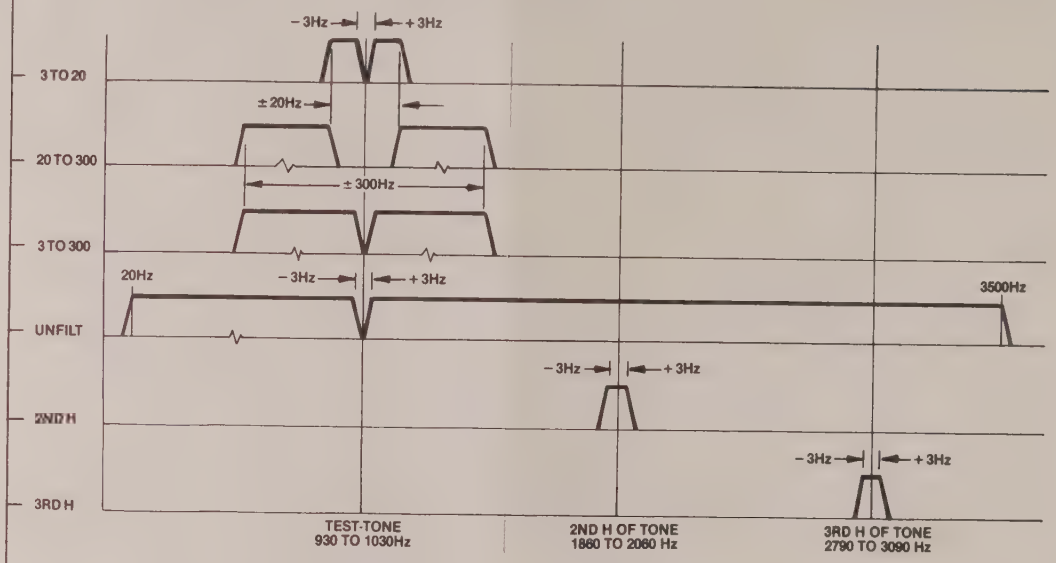
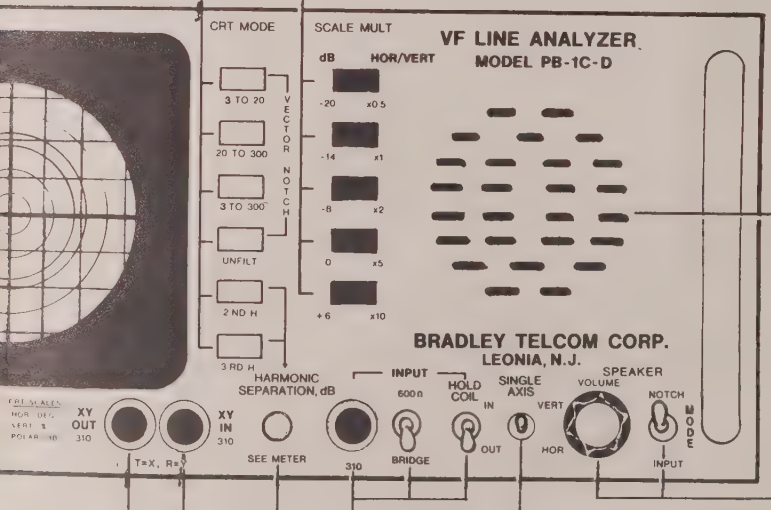
CRT MODE buttons select the following frequency bands:





SCALE MULTiplier buttons select the following ranges:

–20dB	–14dB	–8dB	–0dB	+6dB
x0.5	x1	x2	x5	x10

SPEAKER

SPEAKER VOLUME control adjusts loudness of acoustic output.

SPEAKER MODE Switch determines whether acoustic output is **NOTCH**ed noise or **INPUT** signal repeat.

SINGLE-AXIS Switch has three-positions; spring-return center position (both X and Y deflections), VERT position (Y deflection only), and HOR position (X deflection only).

INPUT Jack accepts signals to be analyzed. Input impedance determined by settings of **600 Ω /BRIDGE** Switch and **HOLD COIL** Switch.

600 Ω /BRIDGE Switch sets input impedance to 600 Ω or Bridging.

HOLD COIL Switch **IN** connects Holding Coil across input; **OUT** disconnects Holding Coil from input.

HARMONIC SEPARATION button. See Second Harmonic Separation and Third Harmonic Separation under DIGITAL MULTI-MODE METER.

XY IN Transfer Jack, when patched, connects patch cord to inputs of CRT deflection amplifiers so instrument can be used as an X-Y oscilloscope or vectorscope. Tip = H or X input; Ring = V or Y input.

XY OUT Jack make available for external recording the voltages at the inputs of the CRT Vertical and Horizontal deflection amplifiers. Tip = H or X input voltage, Ring = V or Y input voltage.

2-7. FUNCTIONS OF CONTROLS, DISPLAYS, AND INDICATORS

2-8. POWER Switch and Fuse. When the PB-1C-D is connected to a power source of rated voltage and frequency by means of a cable plugged into the three-prong receptacle at the left side, the instrument is turned ON and OFF by means of the POWER toggle switch. The instrument is protected by a 0.5A fuse in the fusepost adjacent to the POWER switch.

2-9. INPUT Jack, Switches, and Display. Input signals to be analyzed are fed to the instrument through the 310 INPUT jack. Associated with the INPUT jack are a 600Ω/BRIDGE toggle switch, a HOLD COIL toggle switch, and the fast INPUT LEVEL display.

a. HOLD COIL Switch. When this toggle switch is set to IN, it connects a holding coil across the INPUT jack; when set to OUT, it disconnects the holding coil from the input. The holding coil has a dc resistance of 180 ohms and inductances of 2 henries at 60mAdc and 1.3 henries at 100mAdc.

b. 600Ω/BRIDGE Switch. When this toggle switch is set to 600Ω, it connects a 600 ohm termination across the INPUT jack. The 600 ohm terminating resistor is rated to withstand a 48Vdc central office battery. When the switch is set to BRIDGE, the INPUT jack presents a high input impedance to the input line. The BRIDGE input impedance is greater than 40 kilohms when the HOLD COIL switch is set to OUT, but is reduced by the parallel impedance of the holding coil when the HOLD COIL switch is set to IN.

c. Fast INPUT LEVEL Meter. This 18-bar LED display presents the nearly instantaneous level of the input signal over the range -42 to +9dBm, responding to bursts as short as 20 milliseconds, such as are encountered in polled multi-point data communications networks.

2-10. Digital Frequency Meter and Controls. The four-digit frequency meter measures and displays the frequencies of selected signals over the range 50 to 5000Hz, if the levels of those signals are between -30 and +10dBm. The display is updated twice each second. The signals whose frequencies are to be displayed in the digital frequency meter are selected by means of the NN FREQ and OUTPUT FREQ & LEVEL pushbuttons, as follows:

a. The NN FREQ button causes the frequency of the predominant component of the notched noise (e.g., SFI, a strong harmonic of the test tone, or power-line pickup) in the INPUT signal to be displayed on the frequency meter.

b. The OUTPUT FREQ & LEVEL button causes the frequency of the internal oscillator to be displayed on the frequency meter.

c. When neither the NN FREQ nor the OUTPUT FREQ & LEVEL pushbutton is depressed, the frequency of the input signal is displayed on the frequency meter.

2-11. Digital Multi-Mode Meter and Controls. The four-digit multi-mode meter displays and updates eight times each second the data selected by five interlocked METER MODE pushbuttons (labeled LEVEL, NOISE, NN SEP, AMPL. JITTER, and PHASE JITTER) and four momentary pushbuttons (labeled REMOVE FILTER, ADD LF, OUTPUT FREQ & LEVEL, and HARMONIC SEPARATION) as follows:

a. The LEVEL button causes the dBm level of voice-frequency input signals to be displayed on the multi-mode meter. The range is -39.9 to +9.9dBm, as measured through a power-line-frequency notch filter and a high-frequency noise protection filter. When the REMOVE FILTER button is also depressed, the power-line frequency notch filter is removed, permitting more accurate level measurements at low frequencies.

b. The NOISE button causes the dBrnC level of the noise in the input signal to be displayed on the multi-mode meter. The range is 20 to 70dBrnC (-70 to -20dBm), as measured through a filter with C-Message weighting. When the REMOVE FILTER button is also depressed, the input noise level is measured with the C-Message filter disconnected.

c. The red NN SEP button causes the notched noise separation in dB (i.e., level of notched noise in dB relative to level of quiet tone in the input signal) to be displayed on the multi-mode meter if the CRT is in any VECTOR NOTCH mode. The range is -10 to -50dB, as measured through a C-Message filter. When the REMOVE FILTER button is also depressed, the C-Message filter is disconnected. Note the following:

1. The multi-mode meter will display notched noise separation only if the NN SEP button and one of the four CRT MODE VECTOR NOTCH buttons are depressed.

2. The notched noise separation measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off (see Par. 2-14a).

3. The displayed value of notched noise separation is 14dB less than the input value when the NNE switch is set to ATTEN and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing (see Par. 2-17).

d. The red AMPL. JITTER button causes the percent amplitude jitter of the input signal to be displayed on the multi-mode meter if the CRT is in any VECTOR NOTCH mode. The range is 0 to 30%. The measurement badnwidth is 20 to 300Hz or (if the ADD LF button is also depressed) 3 to 300Hz. Note the following:

1. The multi-mode meter will display amplitude jitter only if the AMPL. JITTER button and one of the four CRT MODE VECTOR NOTCH buttons are depressed. The bandwidth of the amplitude jitter measurement is 20 to 300Hz (or 3 to 300Hz if the ADD LF button is also depressed), regardless of which VECTOR NOTCH button is depressed.

2. The amplitude jitter measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off (see Par. 2-14a).

3. The multi-mode meter will be blanked if the AMPL. JITTER button and either the 2ND H or the 3RD H CRT MODE button are depressed.

4. The displayed value of amplitude jitter is the input value divided by 3.2 when the NNE switch is set to ATTEN and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing (see Par. 2-17).

e. The red PHASE JITTER button causes the phase jitter in degress of the input signal to be displayed on the multi-mode meter if the CRT is in any VECTOR NOTCH mode. The range is 0 to 30°. The measurement bandwidth is either 20 to 300Hz or (if the ADD LF button is also depressed) 3 to 300Hz. Note the following:

1. The multi-mode meter will display phase jitter only if the PHASE JITTER button and one of the four CRT VECTOR NOTCH buttons are depressed. The bandwidth of the phase jitter measurement is 20 to 300Hz (or 3 to 300Hz if the ADD LF button is also depressed), regardless of which CRT MODE VECTOR NOTCH button is depressed.

2. The phase jitter measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off (see Par. 2-14a).

3. The multi-mode meter will be blanked if the PHASE JITTER button and either the 2ND H or 3RD H CRT MODE buttons are depressed.

4. The displayed value of phase jitter is the input value divided by 3.2 when the NNE switch is set to ATTEN, and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing (see Par. 2-17).

f. The OUTPUT FREQ & LEVEL button causes the oscillator output level in dBm to be displayed on the multi-mode meter, regardless of the settings of the METER MODE buttons. The OUTPUT FREQ & LEVEL button also causes the oscillator output frequency in Hz to be displayed on the digital frequency meter.

g. The HARMONIC SEPARATION button causes the second or third harmonic separation in dB to be displayed on the multi-mode meter when the 2ND H or 3RD H CRT MODE button, respectively, is depressed, regardless of the settings of the METER MODE buttons.

2-12. Oscillator Controls, Displays, and Jack. This group comprises a one-turn OUTPUT LEVEL control, five interlocked OSCILLATOR OUTPUT FREQUENCY pushbuttons, a ten-turn 200 TO 5000Hz variable frequency control, a 310 OUTPUT jack, and the OUTPUT FREQ & LEVEL pushbutton described above.

a. The OUTPUT LEVEL control adjusts the oscillator output voltage appearing at the OUTPUT jack to any level between -30 and +9.9dBm. The output level can be set precisely by depressing the OUTPUT FREQ & LEVEL button to monitor the level on the multi-mode meter while adjusting the OUTPUT LEVEL control.

b. The OUTPUT jack has a balanced 600 ohm output impedance, dc-blocked for up to 160Vdc.

c. The OSCILLATOR OUTPUT FREQUENCY pushbuttons select the frequency of the oscillator signal appearing at the OUTPUT jack. The frequencies selected by the buttons are: 2000Hz; 1000Hz, and 2000Hz at -10dB relative to the 1000Hz tone; 1000Hz, 2713Hz; and VARiable, determined by the setting of the 200 to 5000Hz control.

d. The 200 TO 5000Hz control is a ten-turn potentiometer that controls the oscillator output frequency when the VAR button is depressed. The frequency can be set precisely by depressing the OUTPUT FREQ & LEVEL button to monitor the frequency on the digital frequency meter while adjusting the 200 TO 5000Hz control.

e. The OUTPUT FREQ & LEVEL button, as stated in Par. 2-11f, causes the oscillator output frequency to be displayed on the digital frequency meter and (regardless of the settings of the METER MODE buttons) the oscillator output level to be displayed on the multi-mode meter.

2-13. CRT, Graticule, Controls, and Indicator

2-14. In a column at the left of the CRT are, from top to bottom, a DO NOT READ CRT & RED FUNCTIONS indicator and three controls labeled INTENSITY, FOCUS, and SCALE ILLUM. At the right of the CRT are a column of six interlocked red CRT MODE pushbuttons and a column of five interlocked black SCALE MULT pushbuttons. Along the bottom of the panel, below and to the right of the CRT, are two 310 jacks labeled XY OUT and XY IN, and a red HARMONIC SEPARATION momentary pushbutton; further to the right is a SINGLE-AXIS toggle switch.

a. The DO NOT READ CRT & RED FUNCTIONS indicator is off, and all displays are valid, when the phasor-domain AGC and phase-lock loops are locked to the input signal. These loops will acquire and track input frequencies between 930 and 1030Hz, at input levels between -40 and +10dBm. When the AGC and phase-lock loops are not all locked to the input signal, the DO NOT READ CRT & RED FUNCTIONS indicator will light, warning that all CRT MODEs and the NN SEP, AMPL. JITTER, and PHASE JITTER presentations of the digital multi-mode meter are invalid.

b. The INTENSITY and FOCUS controls permit continuous variation of the CRT spot brightness and spot size, respectively. Note the following:

1. Interaction between INTENSITY and FOCUS controls may necessitate readjustment of one when the setting of the other is changed.

2. To avoid burning center of CRT screen if spot remains undeflected for long periods, reduce setting of INTENSITY control. Do not change setting of

FOCUS control, even though the lower-intensity spot may be defocused. When intensity is increased to its former level, the spot will again be in focus.

c. The SCALE ILLUM control permits continuous variation of the graticule scale brightness.

d. The graticule (see Figure 2-3) mounted behind the CRT bezel and in front of the CRT screen has three sets of illuminated scales that are calibrated as follows:

1. The vertical scale is linearly divided by equally-spaced horizontal lines that are numbered along the vertical axis from bottom to top, as follows: -6, -4, -2, (0), +2, +4, and +6. The vertical scale represents percent amplitude jitter, and is read zero to peak.

2. The horizontal scale is linearly divided by equally-spaced vertical lines that are numbered along the horizontal axis from left to right as follows: -3, -2, -1, (0), +1, +2, and +3. The horizontal scale represents angular degrees of phase jitter, and is read peak to peak.

3. The circular or polar scale is logarithmically divided by concentric circles that are numbered inward along a diagonal from the lower left as follows: -10, -12, -14, -16, and -20. The innermost circle, representing -30, is not numbered on the graticule. The polar scale represents dB separation from received tone and is used to read notched noise separation, second harmonic separation, and third harmonic separation.

e. CRT MODE Pushbuttons. There are six red CRT MODE pushbuttons, of which four are VECTOR NOTCH mode pushbuttons (labeled 3 TO 20, 20 TO 300, 3 TO 300, and UNFILT), and two are harmonic mode buttons (labeled 2ND H and 3RD H). In all six modes the AGC and phase-lock loops will lock on to and track input test tones in the amplitude range -40 to +10dBm and the frequency range 930 to 1030Hz; the AGC and phase-lock loops will then normalize the input signal and suppress the test tone. The CRT MODE buttons select various frequency bands of the normalized input signal for resolution into in-phase and quadrature components with respect to the test tone (in the four VECTOR NOTCH modes), the second harmonic of the test tone (in the 2ND H mode), or the third harmonic of the test tone (in the 3RD H mode). In the absence of a patch into the XY IN jack (see Par. 2-14h), the display circuits will present the resolved in-phase and quadrature components as proportional vertical and horizontal deflections, respectively, on the CRT, for visual demodulation by the operator. The signals selected by the CRT MODE buttons for resolution and display are as follows:

1. 3 TO 20. The normalized notched noise (NNN) in the bands 3 to 20Hz below and above the test tone.

2. 20 TO 300. The normalized notched noise in the bands 20 to 300Hz below and above the test tone.

3. 3 TO 300. The normalized notched noise in the bands 3 to 300Hz below and above the test tone.

4. UNFILTered. The normalized notched noise in the band from 20Hz to 3500Hz (except for a ±3Hz notch about the test tone).

5. 2ND H. The normalized components of the input signal within ±3Hz of the second harmonic of the test tone.

6. 3RD H. The normalized components of the input signal within ±3Hz of the third harmonic of the test tone.

f. SCALE MULT Pushbuttons. The CRT display sensitivity is determined by the five SCALE MULT pushbuttons. Each button is labeled with the factor that the horizontal and vertical scales must be multiplied by, and with the number of dB that must be added to or subtracted from the polar scale, when that button is depressed. The corresponding HOR/VERT and polar dB scale modifiers selected by

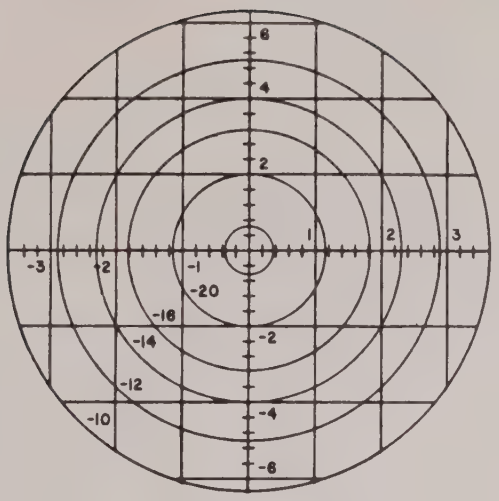


Figure 2-3 Graticule

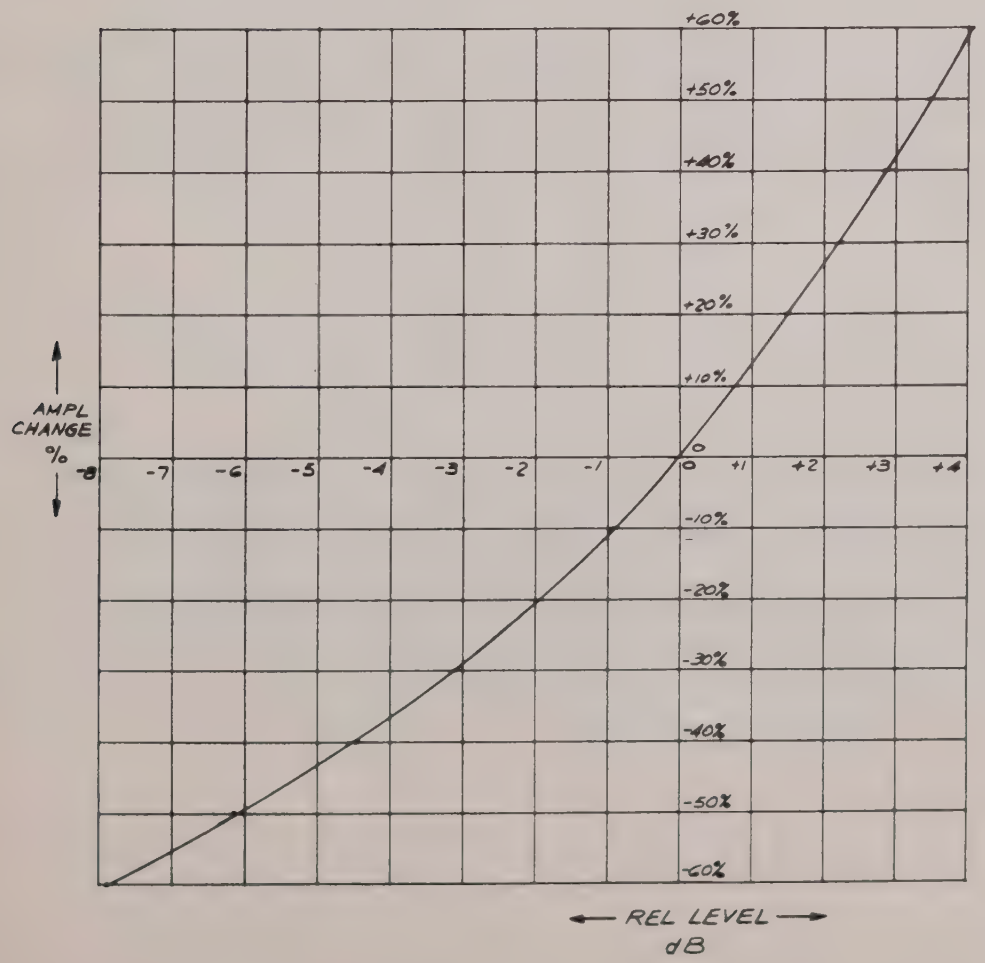


Figure 2-4 Conversion From Percent to dB

the SCALE MULT pushbuttons are as follows:

HOR/VERT	X0.5	X1	X2	X5	X10
Polar dB	-20	-14	-8	0	+6

The following paragraphs show how the SCALE MULT buttons change the values read on the horizontal, vertical, and polar scales.

1. The horizontal scale on the graticule is numbered ±(1,2,3), and the vertical scale is numbered ±(2,4,6). The horizontal scale represents angular degrees, and the vertical scale represents percent change. Although the horizontal and vertical scales represent different units, the same SCALE MULT switch HOR/VERT multiplication factors apply to both simultaneously, as shown in the table below.

SCALE MULT HOR/VERT Settings

		X0.5	X1	X2	X5	X10
Horizontal	1	0.5	1	2	5	10
	2	1.0	2	4	10	20
	3	1.5	3	6	15	30
Vertical	2	1	2	4	10	20
	4	2	4	8	20	40
	6	3	6	12	30	60

2. Phenomena such as gain hits and gain steps are displayed as vertical deflections in percent, but are customarily referred to in dB relative to the tone amplitude. Figure 2-4 is a plot of the relationship between percent change and dB change.

3. The graticule circles used for the polar dB scales are numbered -10, -12, -14, -16, -20, from the outside in. The innermost (-30dB) circle is not numbered. Since the calibrations of the circles represent dB relative to the dB setting of the SCALE MULT switch, the dB value at each setting of the SCALE MULT switch must be added algebraically to the graticule circle values. The following table shows how the dB setting and the graticule reading are added to give the total level in dB of any deflection:

SCALE MULT dB Setting

Graticule Reading	-20	-14	-8	0	+6
-30	-50	-44	-38	-30	-24
-20	-40	-34	-28	-20	-14
-16	-36	-30	-24	-16	-10
-14	-34	-28	-22	-14	- 8
-12	-32	-26	-20	-12	- 6
-10	-30	-24	-18	-10	- 4

g. The SINGLE AXIS switch is a three-position toggle switch with spring return to the center position from either the upper (VERT) or lower (HOR) positions. In the center position, the horizontal signal is fed to the CRT horizontal preamplifier and the vertical signal is fed to the CRT vertical preamplifier, so that the CRT spot can be deflected over the entire screen. In the VERT position, the input to the horizontal preamplifier is grounded so that only vertical deflection is possible. This aids measurement of amplitude jitter on the CRT in the VECTOR NOTCH modes. In the HOR position, the input to the vertical preamplifier is grounded so that only horizontal deflection is possible. This aids measurement of phase jitter on the CRT in the VECTOR NOTCH modes.

h. The XY IN Jack is a transfer jack that permits the PB-1C-D to be used as an X-Y oscilloscope or 'vectorscope' to display modem 'eye patterns', 'constellation patterns', or 'decision spaces'. Many modems have X-Y outputs for this purpose.

1. When the XY IN jack is not used, the outputs of the phasor domain circuits (which are derived from the received signal at the INPUT jack) are fed to the inputs of the CRT Vertical and Horizontal Deflection Preamplifiers.

2. When a patch cord is plugged into the XY IN jack the outputs of the phasor domain circuits are disconnected from the inputs of the CRT deflection preamplifiers, the patch cord tip is connected to the input of the Horizontal (or X) Deflection Preamplifier, the patch cord ring is connected to the input of the Vertical (or Y) Deflection Preamplifier, and the patch cord sleeve is connected to the PB-1C-D ground. The CRT display is then that of an X-Y oscilloscope or vectorscope. Both X and Y inputs have the same nominal deflection sensitivities, which are related to the SCALE MULT switch settings as follows:

SCALE MULT switch setting	X0.5	X1	X2	X5	X10
X,Y IN sensitivities, mV/cm	40	80	160	400	800

3. Since both the X and Y inputs are single-ended, it is necessary to interconnect the grounds of the PB-1C-D and of the source at the other end of the patch cord. The XY IN jack sleeve is connected to the PB-1C-D ground; if the source jack sleeve is connected to the source ground, it is merely necessary to interconnect the two sleeves (i.e., through the third wire of a three-wire patch cord). However if the PB-1C-D and the source are connected to the same power line ground, no further ground interconnection is necessary.

i. The XY OUT Jack makes available for external recording the voltages at the inputs of the CRT Vertical and Horizontal Deflection Amplifiers. The tip voltage is that at the input to the Horizontal Deflection Amplifier, and the ring voltage is that at the input to the Vertical Deflection Amplifier. The amplitudes of these voltages are not affected by the settings of the SCALE MULT switch.

j. The HARMONIC SEPARATION pushbutton is enabled only in the 2ND H or 3RD H CRT MODE. It causes the separation in dB or the selected harmonic (i.e., the level of that harmonic in dB relative to the level of the input quiet tone) to be displayed on the digital multi-mode meter, regardless of the settings of the METER MODE buttons. If depressed when CRT MODE is not 2ND H or 3RD H, the multi-mode reads 0.000.

2-15. The INTERCONNECT A and B Jacks are intended to be patched to the correspondingly-labeled jacks on the Bradley Telcom 75L/PA Hit Counter/Printer Adapter, as shown in Bulletin 3130 at the end of this instruction book. Note that when the PB-1C-D is used with the 75L/PA, the line cord of the PB-1C-D should be plugged into the RFI-filtered receptacle at the rear of the 75L/PA. Since the voltages at the tips and rings of the INTERCONNECT jacks may also be used for other test purposes, they are listed below:

a. INTERCONNECT A Jack

1. The tip voltage is that of the notch phase-lock-loop local oscillator; it is in quadrature with the input signal and is nominally five volts peak to peak when unloaded.

2. The ring voltage is the normalized or AGC'd input signal. When the DO NOT READ CRT & RED FUNCTIONS indicator is off (indicating a valid input signal, i.e., one within the ranges 930 to 1030Hz and -40 to +10dBm), the INTERCONNECT A unloaded ring voltage is a nominal 3.5 volts peak-to-peak sine wave which is offset 4.5Vdc above ground. When the DO NOT READ indicator is on (indicating an invalid signal), the ring voltage is at nominal ground potential.

b. INTERCONNECT B Jack

1. The tip voltage is normalized notched noise (NNN) or normalized input signal with tone removed. The source impedance is 600 ohms, and the level is relative to a 0dBm input when terminated in 600Ω; i.e., the notched noise level in dBm is its separation from the input level in dB. This is independent of the actual tone input level.

2. The ring voltage is the input signal repeated as a single-ended voltage. This is 3 volts peak-to-peak unloaded, when the input voltage is a 2 volt peak-to-peak sine wave (0dBm).

2-16. Rear Connector Access.

The following jacks are repeated at the indicated pin number of the rear connector.

	Tip	Ring
INPUT	24	25
OUTPUT	4	3

Note: Other pins on the connector are used for automatic test adapters. Do not make connections to any other pins without consulting factory.

2-17. Loudspeaker and Controls.

a. The SPEAKER MODE switch selects the audio signal to be fed to the loudspeaker. When the switch is set to INPUT the input signal (quiet tone plus impairments) is fed to the speaker; and when the switch is set to NOTCH, the normalized notched noise (input signal minus quiet tone) is fed to the speaker. This acoustic output is a valuable aid in identifying certain types of impairments by means of their characteristic 'signatures'.

b. The SPEAKER VOLUME control adjusts the loudness of the acoustic output.

2-18. NNE Switch and SCALE CHANGE ON RED FUNCTIONS Indicator. The NNE toggle switch is set to NORMAL except when the input to the PB-1C-D is the output of a remote Bradley Telcom NNE-1000 Series Transparent Line Generator (see Bulletin 4110 at the back of this manual). In that case the NNE-1000 must be set to a NOISE GAIN of 14dB or X5 to increase the notched noise/tone ratio in its output by that factor, and the PB-1C-D NNE switch must be set to ATTEN, to reduce by the inverse factor (i.e., -14dB or X1/5), the sensitivities of all functions controlled by the red pushbuttons (CRT MODE, NN SEP, AMPL. JITTER, and PHASE JITTER), as well as the notched noise voltage at the tip of the INTERCONNECT B jack, and the SPEAKER NOTCH MODE acoustic output. For these settings (i.e., 14dB, X5 NOISE GAIN on the NNE-1000, and NNE ATTEN on the PB-1C-D, the CRT scales and the digital multi-mode meter NN SEP, AMPL. JITTER, and PHASE JITTER scales are direct-reading in terms of the disturbances at the input to the remote NNE. This is equivalent to having a disturbanceless or 'transparent' line between the NNE-1000 and the PB-1C-D, so that the PB-1C-D appears to be making measurements at the input to the NNE-1000 on the other end of the line. To remind the operator of these -14dB or X1/5 scale changes in the NNE ATTEN position, the switch also causes the SCALE CHANGE ON RED FUNCTIONS indicator to flash.

2-19. Rack Adapter Kit. A rack adapter kit is furnished for mounting the PB-1C-D in a standard 19" relay rack. The kit comprises two L-shaped adapter brackets and eight 10/32 x 5/16 flat head (undercut) machine screws. Four countersunk holes in each bracket mate four 10-32 tapped holes in each side wall of the PB-1C-D case. The brackets are fastened to the side wall using the machine screws. The PB-1C-D will fit into a 5-1/4" high rack slot if the feet and bail assembly are removed. The feet are fastened to the case with 6-32 binding head screws and they may be removed by removing the screws. If the feet are replaced at some future time, each front foot (which also supports the bail assembly) is mounted with two 1/2" long screws and each rear foot with one 3/8" long screw. Adapters for 23" telephone racks are also available, on special order.

Section III

THEORY

Sections III and V are now in preparation. When those sections are finished, a copy of the complete manual will be forwarded.

SECTION IV

OPERATION AND DATA INTERPRETATION

4-1. GENERAL

a. Impairment Generators. The use of the PB-1C-D for go/no-go evaluation of VF transmission facilities can be learned in a few minutes; but its use for deep diagnostics requires greater familiarity with the instrument itself and with all the different kinds and combinations of impairments it can display and measure. The time required for the operator to become familiar with the total range of capabilities of the PB-1C-D can be greatly reduced with the aid of an impairment generator which can supply selectable combinations and adjustable levels of known individual impairments. The Bradley Telcom 2A/2B Line Impairment Generator and TIG-1 Tone and Impairment Generator (described in Bulletins 1110 and 1130, respectively, which are appended to this manual) are important teaching and self-training aids for familiarizing personnel with operation of the PB-1C-D and with interpretation of its displays. The 2A/2B is also a powerful aid to the PB-1C-D in the analysis of complex unknown impairments by the method of substitution, because its output, which is a known combination of known levels of known individual impairments, can be adjusted to simulate the unknown impairments when compared with them on the PB-1C-D. Thus, when the controls on the 2A/2B are set so that the PB-1C-D display of the 2A/2B output is similar to the display of the actual impairment to be analyzed, the settings of the 2A/2B controls provide a complete analysis of the impairment. These impairment generators can be purchased from Bradley Telcom or rented from the major electronic instrument leasing companies.

b. One-Way versus Loopback Testing. One-way testing detects impairments in one direction, and loopback testing detects the sum of the impairments in both directions. Impairments observed in one-way testing of a facility but not in loopback testing of that facility are present equally and oppositely in each direction and thus cancel out. The results of loopback testing should therefore be confirmed if possible by one-way testing in at least one of the two directions, to ascertain that there are no significant one-way impairments that have been cancelled out in the loopback. Because the PB-1C-D has both an oscillator output and a signal input, it can easily be used for loopback testing of pairs of lines by patching the oscillator output to the outgoing line, patching the incoming line to the signal input, and connecting the far ends of the lines. With PB-1C-Ds at both ends, it becomes possible to perform one-way tests on either line, or on both lines at the same time, by using the outgoing and incoming lines of the near-end PB-1C-D as the incoming and outgoing lines, respectively, of the far-end PB-1C-D.

c. Remote Tone Sources. When performing one-way testing on an incoming line, it is desirable to have at the far end a precision tone source (e.g., a PB Series Oscillator) or an instrument containing such a source (e.g., a PB-1 Series VF Line Analyzer, NNE Series Transparent Line Generator, or TTL Series Touch-Tone-Addressable Loopback Transponder). Where such tone sources are not available, test tones may be obtained in the following ways:

1. A 1000Hz test tone may be dialed up or patched from supplies located in all central offices. It is well to check the harmonic level of these tone sources, at the originating office if possible.

2. A 941Hz tone may be obtained by depressing any two of the three buttons in the bottom row on Bell System L-C touch-tone pads. The 941Hz tone is within the 930 to 1030Hz tracking range of the PB-1C-D, so that it may be used for vector-notch mode measurements, but its second harmonic content may be high enough to invalidate second harmonic measurements. (If the touch-tone pad is on a telephone, it must be off hook. Room noise will not be a problem, because the microphone is disconnected when the touch-tone buttons are depressed. These statements apply also to 3 below.)

3. 941 and 1555Hz tones are provided simultaneously by depressing 0 and # on Bell System R-C touch-tone pads (used in Trimline phones, etc.); the 20 to 300Hz and 3 to 300Hz vector-notch modes of the PB-1C-D will reduce the 1555Hz tone by approximately 30dB.

d. Because the PB-1C-D operates in real time, two PB-1C-Ds can be used simultaneously to identify the locations of sources of transient impairments with respect

to the facilities being examined. Using one PB-1C-D to examine impairments at the input of the facility and the other PB-1C-D to examine impairments at the output, it is easy to determine, for any transient impairment, whether the facility is initiating or merely transmitting that impairment. Since the PB-1C-D is a VF line analyzer, signals can be accessed directly at VF boards, but accessing in carrier locations will require the use of selective level meters or PCM channel demodulators. Note that the use of a Bradley Telcom NNE Series Transparent Line Generator at the far end of a transmission facility permits accessing both ends of the facility (whether those ends are in the same building or many miles apart) to two PB-1C-Ds at a single near-end location.

e. Most electrical inputs and outputs appearing at jacks on the front panel of the PB-1C-D are repeated at a 25-pin connector on the rear. The outputs may be used to drive external counters, recorders, and displays.

4-2. The PB-1C-D comprises the following test instrumentation:

a. Test Oscillator, with controls, displays, and output jack as described in Par. 2-12.

b. Fast INPUT LEVEL Meter, as described in Par. 2-9c.

c. Digital Frequency Meter, with controls as described in Par. 2-10.

d. Digital Multi-Mode Meter, with controls as described in Par. 2-11.

e. Suppressed-Tone Phasor-Domain CRT, with graticule, controls, jacks and indicator as described in Par. 2-13ff. The CRT can also be used as a vectorscope, by patching horizontal and vertical deflection voltages into the X,Y IN jack on the front panel.

f. Loudspeaker, with controls as described in Par. 2-16.

4-3. OSCILLATOR OPERATION

Panel items related to the internal test-tone oscillator are a one-turn OUTPUT LEVEL control, five interlocked OSCILLATOR OUTPUT FREQUENCY pushbuttons, a ten-turn 200 TO 5000Hz variable frequency control, an OUTPUT FREQ & LEVEL pushbutton, and a 310 OUTPUT jack at which the oscillator output appears as a 600-ohm balanced voltage, dc-blocked for up to 160Vdc.

a. To use the test-tone oscillator output, patch from the 310 OUTPUT jack to the input of the circuit being tested.

b. To read the oscillator output voltage and frequency, depress the METER MODE LEVEL button and hold down the OUTPUT FREQ & LEVEL button; read the oscillator output voltage on the multi-mode meter and read the oscillator output frequency on the frequency meter.

c. To set the oscillator output voltage precisely to any desired value in its -40 to +8dBm range, depress the METER MODE LEVEL button, hold down the OUTPUT FREQ & LEVEL button, and monitor the oscillator output voltage on the multi-mode digital meter while adjusting the OUTPUT LEVEL control.

d. The oscillator output frequency is determined by the settings of the OSCILLATOR OUTPUT FREQUENCY pushbuttons and the 200 TO 5000Hz control, as follows:

1. To obtain a single 1004, 2008, or 2713Hz tone, depress the button labeled 1000, 2000, or 2713, respectively.

2. To obtain a 1004Hz tone with a 2008Hz tone 10dB down from the 1004Hz tone, depress the 1000+2000Hz button. This output is for use with NNE-1000 Transparent Line Generators, but it is useful whenever a tone with a large second harmonic is desired to check facilities for frequency translation or other forms of time-varying phase-intercept distortion.

3. To obtain any output frequency in the range 200 to 5000Hz, depress the VAR button and adjust the 200 TO 5000Hz control.

4. To set the variable output frequency precisely to any desired value in its 200 to 5000Hz range, depress the VAR button, hold down the OUTPUT FREQ & LEVEL button, and monitor the oscillator output frequency on the digital frequency meter while adjusting the 200 TO 5000Hz control.

4-4. FREQUENCY METER OPERATION

The four-digit frequency meter measures and displays the frequencies of selected voiceband signals, if the levels of those signals are between -30 and +10dBm. Panel items related to the frequency meter are the 310 INPUT jack, NN FREQ pushbutton, and OUTPUT FREQ & LEVEL pushbutton.

a. To read the frequency of a tone at the INPUT jack, do not depress either the NN FREQ or the OUTPUT FREQ & LEVEL buttons.

b. To read the frequency of the predominant notched noise component (e.g., SFI, a strong harmonic of the test tone, or power-line pickup) of a nominal 1000Hz signal, hold down the NN FREQ button. The predominant component must be greater than -15dB relative to the tone, and the remaining notched noise must be lower than -20dB relative to the predominant component.

c. To read the output frequency of the internal test-tone oscillator, hold down the OUTPUT FREQ & LEVEL button.

4-5. MULTI-MODE METER OPERATION

The multi-mode meter displays the values of parameters selected by five interlocked METER MODE pushbuttons (labeled LEVEL, NOISE, NN SEP, AMPL. JITTER, and PHASE JITTER) and four momentary pushbuttons (labeled REMOVE FILTER, ADD LF, OUTPUT FREQ & LEVEL AND HARMONIC SEPARATION).

a. To read the average-detected level of the INPUT signal, depress the LEVEL button. The input signal level range is -39.9 to +9.9Bm, as measured through a power-frequency-blocking high-pass filter and a high-frequency-noise-blocking low-pass filter. To make more accurate level measurements at low frequencies, also hold down the REMOVE FILTER button to disconnect the power-frequency-blocking high-pass filter. Note the following:

1. Input levels greater than +9.9Bm will cause all digits to be blanked and dashes to be displayed before and after the decimal point.

2. The level of the input signal can always be read on the fast INPUT LEVEL meter regardless of the settings of the METER MODE buttons, because the INPUT LEVEL meter is connected directly across the INPUT jack and is thus completely independent of the multi-mode meter switches.

3. If the input signal contains neither tone nor data, the meter will indicate the average-detected background noise level of the channel in dBm.

b. To measure the dBrnC level of the INPUT signal, quasi-RMS-detected and C-Message weighted, depress the NOISE button. The range is 20 to 70 dBrnC (-70 to -20dBm). To measure the quasi-RMS-detected level of the INPUT signal in dBrn (i.e., without C-Message weighting, or 'flat'), also hold down the REMOVE FILTER button. Note the following:

1. If the INPUT signal is a test tone or a data signal, the meter will indicate the level of that signal.

2. Only if the input signal comes from a resistively terminated line (i.e., one with neither tone nor data), will the meter indicate the background noise level of that line.

c. To measure the notched noise separation or level in dB relative to the level of

the input tone, with C-Message weighting, depress the NN SEP button. The range is -10 to -50dB. To measure the notched noise separation without C-Message weighting, also hold down the REMOVE FILTER button. Note the following:

1. The multi-mode meter will display notched noise separation:

a) if NN SEP is depressed, regardless of the settings of the CRT MODE buttons;

b) if the HARMONIC SEPARATION button is not depressed.

2. The NN SEP measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator if off (See Par. 2-14a).

3. The displayed value of NN SEP is 14dB less than the input value when the NNE switch is set to ATTEN and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing.

d. To measure the percent amplitude jitter in the INPUT signal over the 20 to 300Hz band, depress the AMPL JITTER button and any CRT MODE/VECTOR NOTCH button. The range is 0 to 30%. To measure amplitude jitter over the 3 to 300Hz band, also hold down the ADD LF button. Note the following:

1. The multi-mode meter will display amplitude jitter only if the AMPL JITTER button and any VECTOR NOTCH/CRT MODE button are depressed. The bandwidth of the amplitude jitter measurement is 20 to 300Hz (or 3 to 300Hz if the ADD LF button is also held down), regardless of which VECTOR NOTCH button is depressed.

2. The amplitude jitter measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off (see Par. 2-14a).

3. The multi-mode meter will be blanked if the AMPL JITTER button and either the 2ND H or the 3RD H CRT MODE button are depressed.

4. The displayed value of amplitude jitter is the input value divided by 5 when the NNE switch is set to ATTEN and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing. (see Par. 2-17).

e. To read degrees of phase jitter in the INPUT signal in the 20 to 300Hz band, depress the PHASE JITTER button and any VECTOR NOTCH/CRT MODE button. The range is 0 to 30°. To measure phase jitter in the 3 to 300Hz band, also hold down the ADD LF button. Note the following:

1. The multi-mode meter will display phase jitter only if the PHASE JITTER button and any VECTOR NOTCH/CRT MODE button are depressed.

2. The phase jitter measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off (see Par. 2-14a).

3. The multi-mode meter will be blanked if the PHASE JITTER button and either the 2ND H or 3RD H CRT MODE button are depressed.

4. The displayed value of phase jitter is the input value divided by 5 when the NNE switch is set to ATTEN and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing. (see Par. 2-17).

f. To read the level of the second harmonic in dB relative to the input tone, depress the 2ND H, HARMONIC SEPARATION and either the LEVEL or the NN SEP buttons. Note the following:

1. The multi-mode meter will display second harmonic separation only if the 2ND H, HARMONIC SEPARATION, and either the LEVEL or the NN SEP buttons are depressed.

2. The second harmonic separation measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off (see Par. 2-14a).

3. The multi-mode meter will display 0 (within 1dB) if the HARMONIC SEPARATION button and any VECTOR NOTCH button are both depressed. This unusually high readout indicates incorrect operation of the instrument.

4. The multi-mode meter will be blanked if the 2ND H button and either the PHASE JITTER or AMPL JITTER buttons are depressed.

g. To read the level of the third harmonic in dB relative to the input tone, depress the 3RD H and HARMONIC SEPARATION buttons, and either the LEVEL or the NN SEP button. Note the following:

1. The multi-mode meter will display third harmonic separation only if the 3RD H, HARMONIC SEPARATION, and either the LEVEL or the NN SEP buttons are depressed.

2. The third harmonic separation measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator if off (see Par. 2-14a).

3. The multi-mode meter will be blanked if the 3RD H button and either the PHASE JITTER or AMPL JITTER buttons are depressed.

4. The multi-mode meter will display 0 (within 1dB) if the HARMONIC SEPARATION button and any VECTOR NOTCH button are both depressed. This unusually high readout indicates incorrect operation of the instrument.

4-6. USE OF THE FAST INPUT LEVEL METER

This meter has no panel controls. It comprises a linear horizontal array of 18 vertical LED bars, each bar being centered under a vertical graduation printed on the panel. The graduations represent 3dBm steps from -42dBm to +9dBm as follows: -42, -39, -36, -33, -30, -27, -24, -21, -18, -15, -12, -9, -6, -3, -0, -3, +6, and +9, of which the underlined numbers are printed on the panel above the corresponding graduations. The fast input level meter circuit measures the positive peak of the input voltage and lights the corresponding LED. Only one LED is actually lit at any instant, although two or more adjacent LEDs may appear lit in response to rapid variations of input voltage levels.

4-7. SPEAKER OPERATION

The acoustic output of the panel-mounted loudspeaker is controlled by the SPEAKER MODE switch and the SPEAKER VOLUME control. The gain of the speaker amplifier is such that low-level inputs will be clearly audible; however, high-level inputs (near 0dBm) will saturate the amplifier if the SPEAKER VOLUME control is set too high. Saturation will be immediately obvious because audible harmonics will be present which disappear at lower SPEAKER VOLUME settings.

a. To hear the entire input signal (tone plus notched noise), set the SPEAKER MODE switch to INPUT, and adjust the SPEAKER VOLUME control for desired sound level.

b. To hear the notched noise in the input signal, set the SPEAKER MODE switch to NOTCH, and adjust the SPEAKER VOLUME control for the desired sound level. Note the following:

1. Since the notched noise is generally much lower than the tone, additional amplification is automatically inserted in the SPEAKER NOTCH MODE.

2. The acoustic output in the NOTCH position of the SPEAKER MODE switch is the notched noise only if the DO NOT READ indicator is off, which occurs only when the input tone is within the ranges 930 to 1030Hz and -40 to +10dBm, and the tracking circuits are locked to the input signal. If the DO NOT READ light is on, the acoustic output of the speaker in the NOTCH mode is the local oscillator only, and may be painfully loud.

3. The notched noise output is very useful, because it permits listening to the

impairments in the input signal without the masking effect of the much larger tone component of the input signal. Each type of impairment has its own characteristic acoustic 'signature' by means of which it can be recognized. Descriptions of the notched-noise acoustic outputs corresponding to the different types of impairments are given in Figures 12 through 29 of Bulletin 2010.

4-8. PHASOR-DOMAIN CRT OPERATION

4-9. VECTOR NOTCH MEASUREMENTS

a. Patch the received signal to the INPUT jack, and set the 600Ω/BRIDGE and HOLD COIL switches for the desired input conditions. Observe that the DO NOT READ CRT & RED FUNCTIONS indicator is off; this means that the PB-1C-D tracking circuits are locked to the input signal.

b. Depress one of the following CRT MODE buttons: 3 TO 20, 20 TO 300, 3 TO 300, or UNFILT. The in-phase component (NNN cos wt) of normalized notched noise is displayed as a vertical deflection, and the quadrature compoment (NNN sin wt) is displayed as a horizontal deflection. The sensitivities of these deflections are controlled by the settings of the SCALE MULT pushbuttons.

c. In-phase or amplitude disturbances deflect the CRT spot vertically; an increase in amplitude deflects the spot upward, and a decrease in amplitude deflects the spot downward. Vertical deflections can be read against the CRT graticule vertical scale, which is calibrated in percent from -6% at the bottom, through -4%, -2%, -0%, +2%, +4%, to +6% at the top. Note that the vertical deflection must be multiplied by the SCALE MULT HOR/VERT factor to obtain the amplitude jitter in percent.

d. Phase or quadrature disturbances deflect the CRT spot horizontally; phase lead deflects the spot to the right, and phase lag deflects the spot to the left. Horizontal deflections can be read against the graticule horizontal scale, which is calibrated in degrees of arc from -3° at the left, through -2°, -1°, (0°), +1°, +2°, to +3° at the right. Note that the horizontal deflection must be multiplied by the SCALE MULT HOR/VERT factor to obtain the phase jitter in degrees. Phase jitter is defined as a peak-to-peak value and is therefore equal to the total horizontal excursion. For example, if the deflection extends from -2° to +2°, the phase jitter reading is 4°.

e. Although the vertical scale is calibrated in percent and the horizontal scale is calibrated in degrees of arc, the multiplier factors (X0.5, X1, X2, X5 and X10) selected by the SCALE MULT buttons apply to both vertical and horizontal scales. When the SCALE MULT X1 button is depressed, both vertical and horizontal deflections may be read directly. For other settings of the SCALE MULT buttons, multiply the graticule vertical and horizontal readings by the scale multiplier factor indicated by the SCALE MULT setting. Note that the deflection sensitivity is reduced by a factor of 5, i.e., x 1/5, when the NNE switch is set to ATTEN.

f. Deflections in any direction may also be measured against polar scale circles that are calibrated in dB from -30dB (the unnumbered smallest circle) through -20dB, -16dB, -14dB, -12dB, to -10dB (the largest circle). Deflections read against the polar scale circles must be added algebraically to the dB level (-20, -14, -8, 0, or +6dB) indicated by the SCALE MULT buttons. Thus, if the -8dB SCALE MULT button is depressed, an impairment that causes a radial deflection to the -14dB circle has a level of (-8) + (-14) = -22dB with respect to the quiet tone. If the -20dB SCALE MULT button is depressed, an impairment that causes a radial deflection to the -30dB circle has a level of (-20) + (-30) = -50dB with respect to the quiet tone. Note that deflection sensitivity is reduced by 14dB when the NNE switch is set to ATTEN.

g. The horizontal deflection only or the vertical deflection only of the CRT display may be examined by holding the SINGLE AXIS switch at HOR or VERT, respectively.

4-10. DISTORTION MEASUREMENTS IN UNFILT VECTOR NOTCH MODE

a. Second and third harmonic distortion can be measured in the UNFILT VECTOR NOTCH mode, as well as in the 2ND H and 3RD H modes described in Par. 4-12 below. Because harmonics of the test tone are coherent with that test tone, in the UNFILT VECTOR NOTCH mode they form cloverleaf patterns that indicate the order of the harmonic. Pure second

harmonic forms a four-lobe cloverleaf pattern and pure third harmonic forms a six-lobe cloverleaf pattern that is folded over into two nearly-coincident three-lobe cloverleaf patterns. These patterns may rotate continuously in the presence of frequency translation (if the distortion occurs before the frequency translation, but not if the distortion occurs after the frequency translation), rotate through limited angles in the presence of low-frequency jitter, or expand and contract in the presence of harmonic hits or of harmonics from multiple sources separated by a transmission facility in which frequency translation occurs. In the UNFILT VECTOR NOTCH mode, distortion levels in dB below quiet tone level are measured on the polar scales in the same way that random-direction radial deflections are measured, as described in Par. 4-9f. Measurements of reasonable accuracy are not feasible unless a single harmonic predominates, which is not usually the case.

4-11. DISTORTION MEASUREMENTS IN 2ND H and 3RD H MODEs

a. The 2ND H and 3RD H buttons select the second and third harmonic distortion components of the received tone for display and measurement. The deflection amplitude is a measure of the distortion magnitude, and the deflection angle is a measure of the phase-intercept distortion of the channel. Since phase-intercept distortion is an uncontrolled parameter, the deflection may be in any direction. It is therefore usually convenient to read the deflection against the circular dB scales. Note again that the dB markings of the SCALE MULT buttons indicate the number of dB to be added to or subtracted from the circle calibrations. In the most sensitive SCALE MULT setting (-20dB), the inner circle (-30dB) corresponds to a separation of -50dB; i.e., the harmonic level is 50dB below the tone level.

b. The measurement is limited by the filter bandwidth, which is made narrow to keep the erratic spot motion induced by background noise below acceptable limits relative to the lowest harmonic distortion measurement threshold (50dB below signal level). Where it is desired to study the phase-intercept distortion, a harmonically-rich 1004Hz + 2008Hz signal can be transmitted by depressing the 1000+2000Hz OSCILLATOR OUTPUT FREQUENCY button. The 2008Hz 'harmonic' will be 10dB below the 1004Hz 'fundamental'.

4-12. MEASUREMENT TECHNIQUES

a. The PB-1C-D can be used to identify and measure each of the impairments defined in Par. 1-20, even when they occur in complex combinations. The discussion in the following paragraphs covers correlated use of the CRT, panel meters, and loudspeaker in identifying and measuring the different kinds of impairments. Such correlated use increases the analytical capabilities of the instrument.

b. Note that the setting of the SCALE MULT buttons must be taken into account when measuring impairments on the CRT. Note also that all CRT measurements, and all digital meter measurements that are controlled by red buttons, are valid only when the DO NOT READ CRT & RED FUNCTIONS indicator is dark.

4-13. NOTCHED NOISE MEASUREMENTS

a. CRT measurements of the notched noise in the input signal can be made in any VECTOR NOTCH CRT MODE. The UNFILT mode provides the greatest amount of information, but depressing the 3 TO 20Hz, 20 TO 300Hz, or 3 TO 300Hz buttons permits measuring the notched noise in those frequency bands. The maximum radial excursion is equal to the peak value of the notched noise. The peak value is more indicative of impairments that cause data errors than is rms noise, because high-speed modems making thousands of decisions per second respond virtually instantaneously to impairments.

b. Multi-Mode Meter readings of the notched noise level (quasi-RMS detected, C-Message weighted, in dB below input tone) can be made when the NN SEP button is depressed. Hold down the REMOVE FILTER button to remove the C-Message weighting, and the meter reading will generally increase because of the added components (predominantly power-frequency pickup), which were not passed by the C-Message filter. A rule of thumb for a 'good' line (i.e., one without too much 60Hz) is that the meter reading should not increase by more than 10dB when the REMOVE FILTER button is held down. Note that this rule of thumb is not a tariff requirement.

c. Speaker output is normalized notched noise when SPEAKER MODE switch is set to NOTCH. Adjust the SPEAKER volume to desired level.

4-14. IMPULSE NOISE MEASUREMENTS

a. CRT measurements of impulse noise hits in the input signal can be made in the UNFILT VECTOR NOTCH mode. Impulse noise hits appear as radial excursions in random directions. The peak excursion is the impulse noise separation in dB relative to the tone. Note that this gives the same impulse noise separation as schemes which measure absolute magnitudes of impulse noise and tone in dBm, and which thus require subtracting the dBm of impulse noise from the dBm of tone to obtain impulse noise separation in dB relative to tone.

b. Multi-Mode Meter response is too slow to measure impulses.

c. Speaker NOTCH MODE output will be clicking or popping sounds simultaneous with the CRT excursions.

4-15. SINGLE-FREQUENCY INTERFERENCE (SFI) MEASUREMENTS

a. CRT displays of pure SFI and of SFI plus steady noise will resemble those shown in Figures 15 and 16 of Bulletin 2010. The experienced operator can diagnose SFI from the CRT display.

b. Multi-Mode Meter cannot measure SFI separately, but only as part of notched noise.

c. Frequency Meter can measure frequency of any predominant notched noise component (e.g., SFI, 2ND H, 3RD H, or power-frequency pickup) when NN FREQ button is held down, if that component is not lower than 15dB below the tone and not lower than 20dB above total of all other notched-noise components.

d. Speaker NOTCH MODE output is a single tone.

4-16. PHASE-JITTER MEASUREMENTS

Note: High noise levels will affect phase jitter measurements.

a. CRT displays of phase jitter show horizontal excursions in all VECTOR NOTCH modes. The UNFILT mode shows all phase jitter components; the 3 TO 20Hz, 20 TO 300Hz and 3 TO 300Hz modes show phase jitter components in those bands only.

1. For each VECTOR NOTCH mode, use the SCALE MULT setting that gives the most readable display.

2. Hold the SINGLE-AXIS switch at HOR, note the excursions to the left and to the right as measured on the horizontal scale, and add the absolute values of the two measurements to obtain the total horizontal excursion.

3. Multiply the total horizontal excursion by the SCALE MULT factor to obtain the phase jitter in degrees.

4. Example: at a X5 SCALE MULT setting, the left excursion is -1.4 and the right excursion is +1.4. The phase jitter is therefore (1.4+1.4)X5 =(2.8)X5=14°.

b. Multi-Mode Meter displays phase jitter when PHASE JITTER button is depressed. Hold down ADD LF button to measure contribution of low-frequency phase jitter.

c. Speaker: the sidebands of pure phase modulation and the hissing sound of noise will both be audible.

4-17. PHASE-HIT MEASUREMENTS

a. CRT displays phase hits as rapid single horizontal excursions in all VECTOR NOTCH modes. The UNFILT mode shows all voice-frequency components of phase hits; to 3 TO 20Hz, 20 TO 300Hz and 3 TO 300Hz modes can be used to measure phase-hit components in those bands.

1. Depress UNFILT mode button.

2. Use a SCALE MULT setting that gives adequate horizontal deflection.

3. Hold SINGLE AXIS switch at HOR and measure on the horizontal scale the maximum excursion, whether to the left or to the right.

4. Multiply maximum excursion by SCALE MULT setting to obtain peak phase hit in degrees.

5. Example: maximum excursion is 2, at X10 SCALE MULT setting. The phase hit magnitude is therefore 2X10=20°. Note that, unlike phase jitter (which is measured peak-to-peak), phase hits are measured zero-to-peak.

b. Multi-Mode Meter cannot detect phase hits.

c. Speaker NOTCH MODE output is a pinging sound, which occurs at same time as CRT excursion.

4-18. GAIN HIT/DROPOUT MEASUREMENTS

a. CRT displays changes in signal amplitude as vertical excursions in all VECTOR NOTCH modes; gain hits and dropouts appear as rapid vertical excursions. The UNFILT mode shows all components of gain hits and dropouts; the 3 TO 20Hz, 20 TO 300Hz and 3 TO 300Hz modes can be used to measure gain-hit/dropout components in those bands.

1. Depress UNFILT button.

2. Select a SCALE MULT setting that gives most readable vertical deflection.

3. Hold SINGLE AXIS switch at VERT and measure on the vertical scale the maximum excursion, whether up or down.

4. Multiply the maximum excursion by the SCALE MULT factor.

b. Multi-Mode Meter cannot detect gain hits or dropouts.

c. Speaker NOTCH MODE output is a pinging sound which occurs at same time as CRT excursion.

4-19. HARMONIC MEASUREMENTS

a. CRT displays second harmonic (in 2ND H mode) or third harmonic (in 3RD H mode). Note: high noise levels will affect harmonic readings by causing erratic spot motion. This can be averaged visually.

1. Depress 1000Hz OSCILLATOR OUTPUT FREQUENCY button, patch oscillator OUTPUT jack to input of facility being tested, and patch output of facility into PB-1C-D INPUT jack.

2. Depress 2ND H button and select SCALE MULT factor giving most readable radial deflection on the dB scale. Measure the radial deflection in dB and add this to the SCALE MULT dB value. Example: CRT radial deflection is -14dB and SCALE MULT setting is -20dB. The sum (-14) + (-20) = -34dB second harmonic. In other words, the second harmonic level is 34dB lower than the tone level, or the second harmonic separation is 34dB.

3. Depress 3RD H button and select SCALE MULT setting giving most readable display. Measure the radial deflection in dB and add this to the SCALE MULT setting to obtain the third harmonic separation.

b. Multi-Mode Meter displays second harmonic separation when 2ND H, HARMONIC SEPARATION, and either the LEVEL or NN SEP buttons are depressed, and displays third harmonic separation when 3RD H, HARMONIC SEPARATION, and either the LEVEL or NN SEP buttons are depressed.

c. Frequency Meter can measure frequency of second harmonic or third harmonic when NN FREQ button is held down, if level of harmonic is not lower than 15dB below the tone and not lower than 20dB above total of all other notched noise components.

4-20. FREQUENCY SHIFT (TRANSLATION)

a. Because frequency shifts in outgoing and return lines can cancel when making loopback measurements, it is necessary to have a harmonically-rich remote source of 1004Hz tone. This remote source may be an NNE-1000, a second PB-1C-D, or other distortion source in the facility ahead of the frequency translation.

b. The local CRT can identify and measure frequency translation, as follows:

1. Depress local 2ND H button.

2. Depress 1000+2000Hz button on remote PB-1C-D, and patch remote oscillator OUTPUT jack to input of facility being tested.

3. Patch output of facility into local PB-1C-D INPUT jack.

4. If a rotation of the display appears, the rate of rotation is equal to the frequency shift or translation caused by the facility under test; e.g., if the display rotates at a rate of 3 revolutions per second, the frequency shift is 3Hz. Direction of rotation indicates direction of shift; ccw is upward shift, cw is downward shift.

c. Multi-Mode Meter does not measure frequency.

4-21. INTERPRETATION OF PB-1C-D CRT DISPLAYS

4-22. GENERAL

a. The illustrations on pages 8 through 11 of Bulletin 2010 represent a catalog of PB-1C-D displays corresponding to various conditions. Those illustrations are useful aids for analysis of impairments by comparison with PB-1C-D displays. Under each illustration is a description of the conditions causing the display, as well as a description of the corresponding sound output, which is a valuable auxiliary aid in diagnosis.

b. The Bradley Telcom Model 2A/2B Line Simulator can be used to cause PB-1C-D displays similar to those caused by the facility under test. The impairments in that facility can then be determined from the 2A/2B control settings that cause the similar display. This substitution technique is especially useful for analyzing 'new' impairments, i.e., those that have not been cataloged previously.

c. With practice, the PB-1C-D operator can learn to analyze even complex displays directly, without recourse to the aids in a. and b. above.

4-23. ANALYSIS OF IMPAIRMENTS IN VECTOR NOTCH MODE

a. Figures 12 through 25 of Bulletin 2010 represent PB-1C-D displays in the 20 TO 300Hz and UNFILT VECTOR NOTCH positions. The left hand photograph of each figure was taken at 20 TO 300Hz, and the right-hand photograph of each figure was taken at UNFILT. The 20 TO 300Hz VECTOR NOTCH filter provides displays compatible with conventional Bell System and CCITT Phase Jitter test sets and with the Bradley Telcom Model 75LMA Phase and Amplitude Jitter Set. However, this filter limits the impairment bandwidths displayed to those in the sidebands 20 to 300Hz below the test tone and 20 to 300Hz above the test tone. In contrast, the UNFILT VECTOR NOTCH mode provides displays showing the entire spectrum of impairments from 30 to 3500Hz, with a notch bandwidth so narrow that all impairment frequencies except those within $\pm$1Hz of the test tone frequency may be observed.

b. In general, phase modulation causes essentially horizontal deflections, amplitude modulation causes vertical deflections, noise causes deflections at random angles, and SFI causes circular motions. If the VECTOR NOTCH pattern is much wider than it is high, phase jitter is predominant. If the pattern is higher than it is wide, amplitude jitter is predominant. We have not had any reports of observed amplitude modulation on any carrier facilities; however, seven-segment PCM systems have quantizing approximation error patterns which are higher than they are wide. Also, the rather large-angle,

low-frequency jitter occasionally present (because of improper phase-lock-loop operation) in FDM systems which recover reference tones from the received signal, produce a second AM-like pair of sidebands which are detected as amplitude jitter. If the display is equally large in all directions, the problem is noise or SFI. In all cases, background noise may be regarded as adding to the modulation impairment; thus, phase modulation plus noise produces a pattern in which the amount of phase modulation can be estimated by subtracting the vertical deflection from the horizontal deflection.

c. An idea of the predominant jitter frequency can be obtained by depressing the various VECTOR NOTCH buttons. Sideband frequencies in the 3 TO 20Hz, 20 TO 300Hz, 3 TO 300Hz and UNFILT ranges will appear when the corresponding buttons are depressed. If there is a predominant single frequency in the modulation pattern, this can be heard on the speaker as two sidebands. For low-frequency jitter, the UNFILT and 3 TO 20Hz VECTOR NOTCH modes are used.

d. If a predominant SFI pattern can be seen in the UNFILT mode but cannot be heard, it is likely to be power-line related components of frequencies at which the small speaker in the PB-1C-D does not have much response.

e. In the detection of modulation impairments by the PB-1C-D, the notched noise is translated downward in frequency by the amount of the test tone and is thus centered at dc with the lower sideband folded back onto the upper sideband. This is accomplished by an internal modulator which multiplies the notched noise by the reference tone. At the same time, the same modulator translates the notched noise up to twice the tone frequency, because the modulator produces the sum as well as the difference frequencies of its two inputs. In the 3 TO 20Hz, 20 TO 300Hz, and 3 TO 300Hz modes, the double-tone-frequency components are filtered out, so that only the dc-centered sidebands are displayed. In the UNFILT mode, both the dc-centered and double-tone-frequency sidebands are displayed. Modulation impairments thus show up two ways in the UNFILT mode. This is really a reflection of the instrumentation used to reduce them to a display and is not a picture of what is actually happening to the tip of the tone vector. It is useful because it 'flags' or calls attention to the modulation impairments, allowing them to be observed even in the presence of a larger amount of noise.

f. In the UNFILT VECTOR NOTCH mode, phase modulation appears as two circles that are tangent to the vertical axis at the origin, and amplitude modulation appears as two circles that are tangent to the horizontal axis at the origin. Transient phase phenomena appear as a circle which expands and contracts to the right or left of the vertical axis at the origin, and transient amplitude phenomena appear as a circle which expands and contracts above or below the horizontal axis at the origin. Low-frequency modulation appears as circles that alternate from one side to the other of the tangent axis, growing and shrinking as they alternate. This process occurs at the jitter frequency. The oscillation frequency may be determined by counting the cycles which occur in a timed interval. The jitter amplitude may be measured by noticing the peak amplitude of the oscillatory motion. The oscillating figure is more or less distinctly delineated, depending on the relative magnitude of the low frequency jitter with respect to the remaining impairments, but the magnitude of oscillation can always be accurately estimated because the pattern motion is distinct, i.e., the edge of the pattern moves an amount equal to the jitter magnitude. The measurement of jitter frequency is important because all low-frequency jitter meters (including the Bradley Telcom Model 75L, as well as the PB-1, PB-1C and PB-1C-D), start to roll off at 3Hz. However, since the jitter frequency can be observed, the curve of Figure 4-1 can be used to correct the reading. Many cases of low-frequency jitter observed with the PB-1C-D display a jitter frequency of between 1 and 2Hz and a corrected jitter magnitude in excess of 25 degrees.

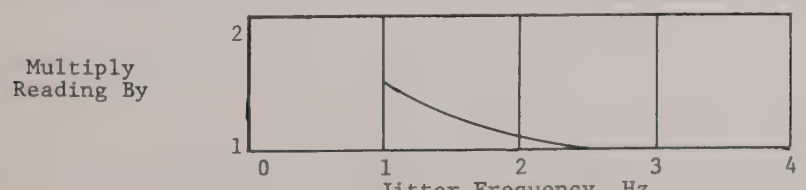


Figure 4-1 Correction For Jitter At Low Frequencies

g. Gain hits are tone-correlated impairments which cause vertical deflections and pinging or (if short enough) popping sounds. Phase hits are tone-correlated impairments which cause horizontal deflections and pinging or (if short enough) popping sounds. Simultaneous gain and phase hits (called 'coincidence hits') cause deflections at angles between the vertical and horizontal, and pinging or (if short enough) popping sounds. Repeated coincidence hits will generally cause repeated deflections at approximately constant angles. Impulse hits (also called impulses and impulse noise) are non-tone-correlated impairments which cause deflections in random directions, and popping sounds.

h. FDM channels (e.g., L and N carriers) tend to have tone-correlated phase impairments. FDM systems in which the demodulation reference is transmitted with the signals have failure modes in which low-frequency phase jitter predominates. FDM systems with an independent sync chain have predominant jitter in the 20 to 300Hz passband. These latter systems may display some varying phase-intercept distortion (slow phase hit) or continuous small phase hits. These latter hits are usually brief in duration.

i. PCM systems (e.g., T-carriers) are characterized by noise-like patterns, which are actually complex Lissajous figures in which (for seven-segment systems) the in-phase impairment usually exceeds the quadrature impairment. T-carrier noise patterns may have peculiar systematic shapes which vary quite noticeably with tone frequency as it affects the sampling frequency foldback products. The shapes differ between manufacturers, reflecting the different design choices made by each. The acoustic output has an easily-identifiable characteristic sound like that of gears grinding.

4-24. DISTORTION ANALYSIS IN THE UNFILTERED VECTOR NOTCH MODE

a. Figures 26 through 29 of Bulletin 2010 show second and third harmonic distortion in the UNFILT VECTOR NOTCH mode. Such distortion is visible in the UNFILT mode, but is out of the passbands of the 3 TO 20Hz, 20 TO 300Hz, and 3 TO 300Hz filters.

b. Because harmonics of the test tone are coherent with that test tone, they form cloverleaf patterns that indicate the order of the harmonic. Pure second harmonic forms a four-lobe cloverleaf pattern; pure third harmonic forms a six-lobe clover-leaf pattern that is folded to make two nearly-coincident three-lobe cloverleaf patterns. Continuously rotating patterns indicate that frequency translation is occurring after the distortion. Rotation of the pattern through limited angles indicates low-frequency jitter. Expanding and contracting patterns without rotation indicate harmonic hits.

4-25. HARMONIC DISTORTION ANALYSIS IN THE 2ND H AND 3RD H MODES

a. The 2ND H and 3RD H CRT MODE buttons select the second and third harmonic distortion components of the received tone for display and measurement. Figure 31 in Bulletin 2010 is a typical 2ND H or 3RD H display. The deflection amplitude is a measure of the distortion magnitude, and the deflection angle is a measure of the phase-intercept distortion of the channel. Since phase-intercept distortion is an uncontrolled parameter, the deflection may be in any direction.

b. When frequency translation is present, the phase-intercept distortion angle changes continuously at a constant rate and the spot moves in a circular path, as shown in Figure 31B of Bulletin 2010. The impairment location causing it is shown in Figure 30. Note that at the receive terminal, the frequency of distortion content, $k_T \cos (2wt + st)$ differs from twice the frequency of the fundamental, $\cos 2(wt + st)$, by the amount st. This is the equivalent of an SFI input at a beat frequency st.

c. When second harmonic distortion, $k_R \cos (2wt + 2st)$, is introduced at the receive terminal after the frequency translation, it is distortion of the received frequency; it is thus exactly double the received frequency and produces a stationary spot. In Figure 31C, note that the circle radius (k_T) corresponds to the distortion which occurs ahead of the frequency translation; the offset (k_R) of the center of the circle corresponds to the distortion which has occurred after the frequency translation; and the rate at which the circle is traversed by the spot is a measure of the frequency of translation. The foregoing analysis may be extended to third harmonic distortion.

d. There may be multiple frequency translation sources as well as other phenomena which cause variations in the phase-intercept distortion angle. Phase hits cause in-

termittent angular motion of the spot. Phase modulation causes oscillatory angular motion of the spot. Filters limit the display bandwidth in the harmonic modes so that only low-frequency jitter can be thus observed. There may also be harmonic amplitude hits, usually involving PCM carrier, which cause radial motion of the spot. Large irregular or jagged circles encountered in PCM systems are an indication that the compandor or the aliasing filters are not functioning properly. Depending upon its magnitude, this phenomenon may render a facility incapable of passing data. This particular problem is not observable with conventional test equipment because the filtering involved in reducing the phenomenon to a meter reading severely attenuates the impairments. There are normally multiple distortion sources, although in a trouble situation one will usually predominate. These phenomena may occur at any voice appearance in the transmission path, with unpredictable phase-intercept distortion between their point of generation and the final output. The result is spot motion in random directions. The operational significance of the above is that if the distortion spot displays high mobility it is an indication that the channel will have trouble passing data.

4-26. PHASE-INTERCEPT DISTORTION. (See Figure 32 of Bulletin 2010)

a. The time delay suffered by any frequency component passing through a transmission medium is the slope of the line joining that point on the curve with the origin on a phase vs. frequency plot. One condition required for undistorted transmission of a complex wave shape is that the phase vs. frequency curve (plotted in linear units, and extrapolated down to dc) be a straight line passing through the origin. This is the response corresponding to a pure time delay. The slope of this line is the time delay, t. Dimensionally, $\phi/w=t$; radians/(rad/sec)=sec. Intuitively there is no time-domain wave-shape distortion because all frequency components have the same time delay and therefore arrive in the same relative phase at the far end as they leave at the launching end.

b. Note that a perfectly linear phase vs. frequency curve (zero envelope-delay distortion) is not a sufficient condition for low baseband distortion because, referring to Figure 32 of Bulletin 2010, the time delay ϕ_1/w_1 of frequency component w_1 is entirely different from the time delay ϕ_2/w_2 of frequency component w_2. This distortion is a result of the angle at the extrapolated intersection of the phase vs. frequency curve with zero frequency. This is known as the phase-intercept distortion. It is an uncontrolled parameter in most communications systems, and it is the reason for the existence of modems, which compensate for phase-intercept distortion.

c. The angular displacement of the spot for either second or third harmonic distortion measurement is a measure of the phase-intercept distortion. In the mechanization of the PB-1C-D the received tone, cos $(wt + \phi_w)$ is tracked. It is then doubled, i.e., cos $(2wt + 2\phi_w)$. The phase and amplitude of the second harmonic cos$(2wt + \phi_{2w})$ is plotted with respect to the double-frequency tone as a reference. Referring to Figure 33 of Bulletin 2010, which is a phase vs. frequency plot, the phase difference between cos $(2wt + 2\phi_w)$ and cos $(2wt + \phi_{2w})$ is $(2\phi_w - \phi_{2w})$. This is the deflection angle of the harmonic distortion spot. It is also the phase-intercept distortion based on measurement at frequencies w and 2w. A similar observation is true with respect to the third harmonic.

d. Angular motion of the harmonic 'spot' corresponds to changes in phase-intercept distortion. This motion will always be along an arc of some circle for a given distortion source and the phase-intercept distortion due to that source. However, several harmonic distortion sources may exist in a transmission channel relative to several phase-intercept distortion sources. The case of frequency translation described above is commonly encountered.

e. The measurement is limited by the filter bandwidth. This must be narrow to keep the erratic spot motion induced by background noise within acceptable limits relative to the lowest harmonic distortion measurement threshold (50dB below signal level). Where it is desired to study the phase-intercept distortion, a harmonically rich signal can be transmitted by depressing the OSCILLATOR OUTPUT FREQUENCY 1000+2000Hz button. This raises the harmonic level above the noise level. The presence of a highly mobile harmonic spot when an FDM system is probed in this way is an indication that the primary frequency supply is in trouble. This phenomenon, which can only be observed in the phasor domain, is data-inimical. It renders modems (as opposed to limited-distance modems or line drivers) incapable of compensating for the phase-intercept distortion angle which is the only reason for their existence in the first place.

4-27. SELF CHECK OF PB-1C-D

The following steps constitute a self-check procedure. This self-check procedure should be employed for initial checkout of the PB-1C-D immediately after receiving and unpacking the instrument. It should also be employed whenever anomalous behavior or malfunction occurs, but only after possibility of operator error has been investigated and eliminated.

a. Start-Up

1. Set POWER switch to OFF. Plug female end of power cable into recessed male receptacle on left side of the PB-1C-D, plug male end of power cable into a 115Vac/60Hz single-phase grounded outlet, and patch OUTPUT jack to INPUT jack.

2. Set NNE switch to NORMAL, 600Ω/BRIDGE switch to 600Ω, HOLD COIL switch to OUT, SPEAKER MODE switch to INPUT. Depress OSCILLATOR OUTPUT FREQUENCY 1000Hz button and METER MODE LEVEL button. Rotate SPEAKER VOLUME control to its ccw stop, and rotate oscillator OUTPUT LEVEL control to its cw stop.

3. Set POWER switch to ON. The DO NOT READ CRT & RED FUNCTIONS indicator should light and go out after a few seconds. The frequency meter should then indicate approximately 1004Hz, the multi-mode meter and the INPUT LEVEL meter should both indicate between 5 and 10dBm, and the speaker output should be the 1004Hz tone.

4. Depress CRT MODE 3 TO 300Hz button and SCALE MULT -20dB/X0.5 button. Adjust SCALE ILLUM control to setting at which graticule illumination is visible, but at which scattered light from graticule does not increase background light level on CRT screen. Adjust INTENSITY and FOCUS controls for sharpest spot on CRT screen. Spot should be within smallest circle; i.e., spot deflection should be less than -50dB (sum of -30dB of smallest circle and -20dB SCALE MULT setting).

b. 1004Hz Checks

1. Slowly rotate OUTPUT LEVEL control to its ccw stop. Note that, unless rotation is very slow, CRT spot jumps up and down while OUTPUT LEVEL control is rotated. This reflects time required for the AGC loop to adjust to change in input level. There may also be some noise generated by the rotating arm of the potentiometer. The multi-mode and INPUT LEVEL meter indications should decrease together to -35dBm or less at ccw stop of OUTPUT LEVEL control. Speaker output should decrease until it become inaudible. At low levels, with the SPEAKER MODE switch set to NOTCH, the 60Hz power-frequency background noise becomes significant, and may be heard as a buzzing sound. Frequency meter indication should remain at 1004Hz.

2. Adjust OUTPUT LEVEL control for approximately 0dBm on multi-mode and INPUT LEVEL meters. Speaker output should become audible again. Read frequency meter and multi-mode meter. Hold down OUTPUT FREQ & LEVEL button and read both meters again. Frequency meter reading should not change at all; multi-mode meter reading should not change more than .3dB.

3. Slowly increase SPEAKER VOLUME until 1004Hz tone is fairly loud, then set SPEAKER MODE switch to NOTCH. Speaker output should decrease to a very low background noise level.

4. Gain Steps

a) Depress SCALE MULT +6dB/X10 button. Generate a positive gain step by setting the 600Ω/BRIDGE switch to BRIDGE. CRT spot should jump upward and quickly return to center. Speaker output should be a 'ping'. Multi-mode and INPUT LEVEL meter indications should increase from 0dBm to +6dBm.

b) Generate a negative gain step by setting the 600Ω/BRIDGE switch to 600Ω. CRT spot should jump downward and quickly return to center. Speaker output should be a 'ping'. Multi-mode and INPUT LEVEL meter indications should return to 0dBm.

c) Depress CRT MODE UNFILT button, and repeat 4a). Note that, instead of the CRT spot jumping up and quickly returning to center, a circle tangent to the hor-

izontal axis forms above that axis and then collapses.

d) With the CRT MODE UNFILT button depressed, repeat 4b). Note that instead of the CRT spot jumping downward and quickly returning to center, a circle tangent to the horizontal axis forms below that axis and then collapses.

5. Phase Steps

a) Depress CRT MODE 3 TO 300Hz button and SCALE MULT -20dB/X0.5 button. Set SPEAKER MODE switch to NOTCH. Generate a positive phase step by setting the HOLD COIL switch to OUT. CRT spot should deflect to right and then return to center. Speaker output should be a 'ping'.

b) Generate a negative phase step by setting the HOLD COIL switch to IN. CRT spot should deflect to left and then return to center. Speaker output should be a 'ping'.

c) Depress CRT MODE UNFILT button and generate a positive phase step by setting the HOLD COIL switch to OUT. Note that instead of CRT spot jumping to right and returning to center, a circle tangent to vertical axis forms to right of vertical axis and collapses.

d) With the CRT MODE UNFILT button depressed, generate a negative phase step by setting the HOLD COIL switch to IN. Note that instead of CRT spot to jumping to left and returning to center as in b) above, a circle tangent to the vertical axis forms to left of vertical axis and then collapses towards the vertical axis.

6. Comparison of dBm, dBrnC, and dBrn Levels

a) With LEVEL button depressed, adjust OUTPUT LEVEL control for approximately -30dBm on multi-mode meter.

b) Depress NOISE button. Multi-mode meter indication should change to approximately 60 dBrnC.

c) Hold down REMOVE FILTER button. NOISE reading may increase 0.1 to 0.2dB, depending on local grounding. Since C-Message filter has been removed, the NOISE reading is no longer in dBrnC but in dBrn.

c. 1004+2008Hz Checks

1. Depress OSCILLATOR OUTPUT FREQUENCY 1000+2000Hz button. The oscillator output is now a 1004Hz 'fundamental', with a 2008Hz 'second harmonic' 10dB down from the 1004Hz level set by the OUTPUT LEVEL control. The input circuits will lock to the 1004Hz tone, the DO NOT READ lamp will go out, and the CRT spot will appear at the center of the screen. The frequency meter should indicate the 1004Hz tone.

2. Comparison of LEVEL, NOISE, and NN SEP Indications

a) Depress LEVEL button and adjust OUTPUT LEVEL control for -30dBm indication on multi-mode meter.

b) Depress NOISE button. Multi-mode meter indication should change to approximately 60 dBrnC.

c) Hold down REMOVE FILTER button. Multi-mode meter indication may increase slightly.

d) Depress NN SEP button. Multi-mode meter indication should change to approximately -10dB, which is the level of the 2008Hz notched noise relative to the 1004Hz tone.

3. Set SPEAKER MODE switch to INPUT; the speaker output should be 1004Hz tone with a large (30%) 2008Hz second harmonic. Set SPEAKER MODE switch to NOTCH; the speaker output should be a 2008Hz tone.

4. Depress CRT MODE 3 TO 20Hz and SCALE MULT -20/X0.5 buttons. CRT spot should remain at center of screen.

5. Depress CRT MODE 20 TO 300Hz button. The CRT spot should become a nominally -50dB circle indicating that the 20 to 300Hz filter (whose upper limit is 300Hz above the 1004Hz tone) has attenuated the -10dB, 2008Hz 'second harmonic' by approximately 40dB relative to the 1004Hz 'fundamental'.

6. Depress CRT MODE 3 TO 300Hz button. The SFI circle diameter should remain about -50dB as in previous step, indicating that the 3 to 300Hz filter has attenuated the -10dB, 2008Hz 'second harmonic' by 40dB relative to the 1004Hz 'fundamental'.

7. Depress CRT MODE UNFILT button. The CRT display should change and expand so that its extremes are off screen. (It may be necessary to increase INTENSITY setting). Successively depress SCALE MULT -14dB/X1, -8dB/X2, 0dB/X5, and +6dB/X10 buttons until, at the last setting, a complete four-leaf clover appears on the CRT screen.

a) Note that the maximum diameter of the cloverleaf is -16dB (the graticule scale calibration) +6dB (the SCALE MULT setting) = -10dB.

b) Check vertical and dimensions of the four-leaf clover by setting SINGLE-AXIS switch to VERT and then to HOR.

c) Set NNE switch to ATTEN. SCALE CHANGE ON RED FUNCTIONS indicator should flash, and diameter of four-leaf clover should decrease 14dB. Check this reduction by depressing the SCALE MULT -8dB/X2 button, which should restore the cloverleaf to its original size. Set NNE switch to NORMAL and SCALE MULT switch to +6dB/X10.

8. Depress CRT MODE 2ND H button. CRT spot should deflect in some direction to the -16dB circle. The value of the deflection will be -16dB+6dB = -10dB. Confirm this by holding down the HARMONIC SEPARATION button; the multi-mode meter should read approximately -10dB.

d. 2008Hz Check. Set OUTPUT LEVEL control to cw stop and depress OSCILLATOR OUTPUT FREQUENCY 2000Hz and METER MODE LEVEL buttons. The DO NOT READ indicator should light and the CRT spot should be deflected downward off screen, because there is no tone in the range 930 to 1030Hz for the input circuits to lock to. Frequency meter and speaker output (with SPEAKER MODE switch in either NOTCH or INPUT positions) should both indicate 2008Hz.

e. 2713Hz Check. Depress OSCILLATOR OUTPUT FREQUENCY 2713Hz button. The DO NOT READ indicator should remain lit, and the CRT spot should remain deflected off screen, because there is no 930 to 1030Hz tone for the input circuits to lock to. Frequency meter and speaker output (with SPEAKER MODE switch in either NOTCH or INPUT positions) should both indicate 2713Hz.

F. 200 TO 5000Hz VAR Check

1. Rotate 200 TO 5000Hz control to ccw stop, and depress OSCILLATOR OUTPUT FREQUENCY VAR button. Frequency meter and speaker output (in either INPUT or NOTCH MODE) should both indicate 200Hz or less. CRT spot should be off screen and DO NOT READ CRT & RED FUNCTIONS indicator should be lit, because there is no 930 to 1030Hz tone for the input circuits to lock to.

2. Slowly rotate 200 TO 5000Hz control clockwise, noting increasing frequency on frequency meter and in speaker output. Note that at about 930Hz, input circuits lock to oscillator output, DO NOT READ indicator goes out, CRT spot jumps to center of screen, and speaker output (with SPEAKER MODE switch set to NOTCH) drops sharply. Continue rotating 200 TO 5000Hz control slowly cw. Note that at about 1030Hz, input circuits can no longer remain locked to oscillator output, DO NOT READ indicator lights, CRT spot is deflected downward off screen, and SPEAKER NOTCH MODE output increases sharply. Continue rotation and observe upper frequency limit of approximately 5000Hz.

Section V

ALIGNMENT

Sections III and V are now in preparation. When they are finished, a copy of the complete manual will be forwarded.

Technical Bulletin

SUPPRESSED TONE PHASOR DOMAIN MEASUREMENT

SUMMARY

A new measurement technique is described for examining a sinusoidal signal. The sinusoid itself is suppressed. The remaining signal components are normalized relative to the tone and are classified in the phasor domain, either relative to the tone, or relative to its harmonics. The result is a remarkable informative real time visual demodulation of the disturbances of the sinusoid. The technique is generally applicable but it is described relative to a telephone transmission channel instrument which is its first application. In this application both go/no-go facility testing for modem compatability, and in-depth diagnostic examination for facility evaluation, are carried out by the same instrument. This derives from the fact that the visually demodulated tone impairments are displayed in the same way that those same impairments are electronically demodulated by the modem receiver, or are as they are superimposed on the tone by the facility.

Frank Bradley

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1. INTRODUCTION

The major thrust for the improvement of telecommunication instrumentation derives from the need:

1. To quickly "clear" a facility in the case of a complaint which is not valid.
2. To quickly "tag" a facility in the case of a complaint which is valid.
3. To identify the nature of the impairment for facility maintenance personnel who are trying to clear troubles.
4. To classify facilities in a go/no-go way relative to modem requirements for data-concerned personnel.

These functions appear to be well served by the suppressed-tone phasor domain approach. In this approach the impairments induced by the facility on a test tone are visually demodulated and displayed in real time. Impairments are thereby distinguished with a resolution which is unique. Because of the excellent delineation of the presentation, a meaningful examination of the entire voice band can be carried out at one time and on one display. The present instrumentation (PB-1) thus not only provides results extremely quickly, but it is the only existing hardware which can positively "clear" a facility against suspicion of all the dynamic impairments, including those which have been defined and are now measured by conventional equipment, and those which have not yet been defined. This occurs because the impairment examination is not limited by a set of rules for detection and time averaging as required to produce a numerical display. As a corollary, the instrument does not become obsolete from time to time as new impairments are discovered or rules changed.

Because it examines a facility in the same real time way that modems use that facility, it provides a direct comparison of facility performance vis a vis modem requirements. The same instrument provides valid go/no-go screening capability for relatively unskilled personnel and deep diagnostic information for the more sophisticated user. There is a desirable side benefit, users of the PB-1, at whatever level, develop better insight into the nature of impairments.

An interesting aspect of the technique is elicited by the question "Just what is it that is being measured?" This is most frequently asked when the PB-1 is monitoring a quiet line, because nothing much seems to be happening. The answer is "Everything," i.e., all dynamic impairments. The absence of activity denotes a highly desirable condition because the display not only indicates what impairments are present, but *what impairments are not present*. Usually one or two parameters will predominate, depending upon the type of facility, and their magnitude can be measured. Of equal or greater importance is the information, implicit in the display, that everything else is negligible.

2. TESTING OF VOICE AND DATA TRANSMISSION FACILITIEES

The telephone network was designed primarily to route and transmit voice communications. The performance characteristics of the voice-frequency channels of the telephone

Figure 1 Suppressed Tone Phase Domain Instrument

network are therefore not optimized for transmission of digital data. As a result, problems frequently arise in the transmission of data over the telephone network, and those problems increase greatly with the rate of data transmission. When subscribers use data sets or 'modems' supplied by common carriers, to transmit and receive data over common carrier telephone facilities, the major responsibility for solving any data transmission problems is obviously that of the carriers. However, when subscribers use modems not supplied by common carriers, to transmit data over common carrier telephone facilities, the responsibilities for data transmission problems may not be so clear. Such problems may arise because of deficiencies in the modems, in the facilities, or in both. It then becomes desireable for both subscribers and common carriers to be able to test the telephone network facilities, in order to determine the sources of problems. Such testing must be made not only against voice transmission criteria, but also against data transmission criteria.

Telephone network transmission channels perform differently when loaded and when idle. Since only channels loaded with data can induce disturbances on that data, they are preferably tested in the loaded condition. One method of loading a channel for testing is to transmit a 'holding'

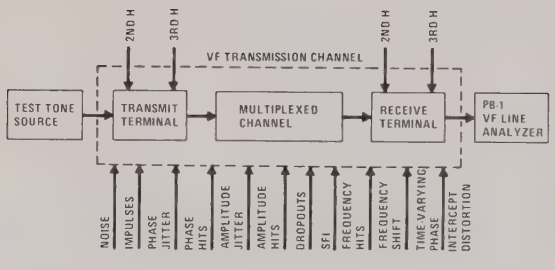

Figure 2 One-Way Facility Testing

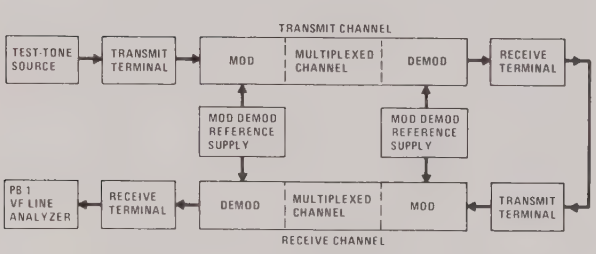

Figure 3 Loopback Facility Testing

tone through that channel. The Model PB-1 VF Line Analyzer, see Figure 1, utilizes such tones as test tones. This instrument, which is the first embodiment of the suppressed-tone phasor domain measurement technique, monitors the tone (i.e., after transmission through channels under test) for disturbances induced on that tone by channel impairments. Figure 2 shows the basic configuration for one-way testing of a telephone transmission facility, and Figure 3 shows the configuration for loopback testing. Various types of disturbances that can be induced on a test tone are shown in Figure 2. Harmonic distortion is introduced only at the terminals because harmonics occurring after the channel has been multiplexed will fall out of band. Although not shown in Figure 3, the disturbances shown in Figure 2 can be introduced into both the transmit and receive channels of a loopback connection. One-way testing detects disturbances in one direction, and loopback testing detects the sum of the disturbances in both directions. In loopback testing, some disturbances may be introduced equally and oppositely in each direction, and thus cancel out, e.g., reference supply problems. Thus, though loopback testing may be more convenient, the results of such testing should be confirmed if possible, by one-way testing in at least one of the two directions, to ascertain that there are no significant one-way impairments that have been canceled out by looping back.

3. CLASSIFICATION OF LINE DISTURBANCES

The test tone, cos wt, as received via the communication channel has disturbances which are synchronous with the test tone and disturbances which are not. This is reflected by the expression below in which g(t) and p(t) are respectively disturbances on the amplitude and phase of the received tone, and $H_k \cos(kwt + \Phi_{kw})$ is the harmonic distortion where k assumes integral values of 2 and over. N(t) are disturbances which are not correlated with, or synchronous with, the received tone.

$$\text{Received tone } V_r = A_w \left[1 + g(t)\right] \cos(wt + p(t)) + N(t) + H_k \cos(kwt + \Phi_{kw})$$

Note that the reference in this discussion is the received tone $A_w \cos wt$. This takes no account of the channel phase shift, frequency shift, or echo. It does consider the difference in phase shift between the tone and its harmonics, Φ_{kw}, a matter of considerable significance, see below.

4. TONE-CORRELATED AMPLITUDE DISTURBANCES (See Figure 4)

The correlated disturbances which affect tone amplitude are incidental amplitude modulation, amplitude hits, amplitude steps, and dropouts. g(t) is that function of time which describes the amplitude variation of the test tone. It involves a relatively steady state component having a zero time average over the measurement bandwidth of the test instrument. This is "amplitude modulation".* g(t) also has a discontinuous component having a non-zero short time average. This component is called an amplitude hit or amplitude step. An amplitude step is a positive or negative step in g(t). It is measured with respect to the recent average level of the test tone subject to certain rise time and amplitude criteria. An amplitude hit is bi-directional, i.e., a step to a new value and then a return to more or less the original value. A dropout is a large decrease in level or short term loss of signal measured with respect to the received tone level at the time a test is started or other appropriate reference level. Note the difference between a dropout and a gain hit. The latter is defined with respect to a recent average level of the received tone, also there is no rise time criterion for a dropout, merely a level threshold and a minimum duration. The recently promulgated Bell System definition for a dropout is "a reduction in the received tone voltage level by more than 12 dB with respect to its value at the start of the test, which level stays below this threshold for 4 milliseconds or more". In suppressed phasor representation, amplitude jitter appears as a vertical line. Its length is a measure of the magnitude of the jitter. Hits appear as transient vertical excursions, either uni-directional or bi-directional dependent on their time history. The AGC tracking loop of the PB-1 suppresses transient excursions in the long term, but it does not do so instantaneously, otherwise both jitter and hits would be masked. Rather it tracks transient with a time constant of nominally 50 milliseconds so that recovery from a step transient is relatively complete within 1/7 second.

5. TONE-CORRELATED PHASE DISTURBANCES (See Figure 5)

p(t) is that function of time which describes the short term phase variation. It involves a relatively steady state component having a zero time average over the instrumentation

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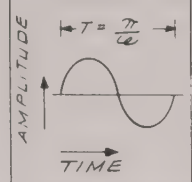
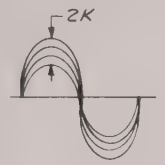
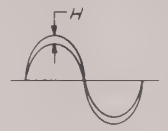
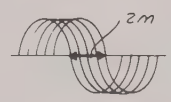
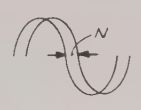
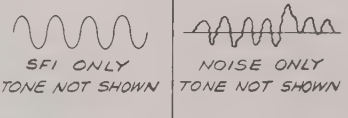
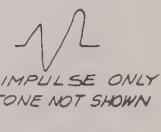
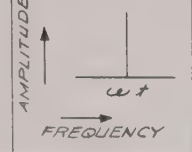
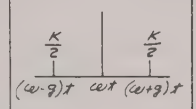
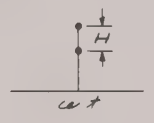
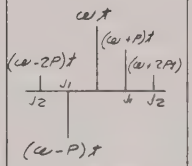
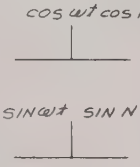
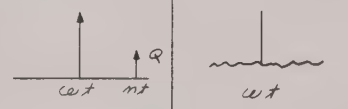
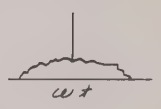
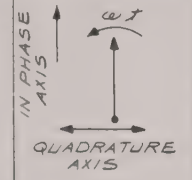
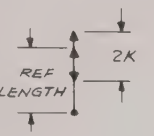
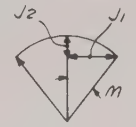
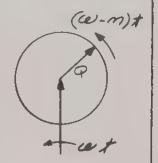
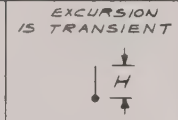
*Amplitude jitter is the sum of the effect of Incidental Amplitude Modulation and noise within the jitter filter bandwidth on the signal amplitude.

Figure 4 Figure 5 Figure 6

		TONE-CORRELATED AMPLITUDE DISTURBANCES A		TONE-CORRELATED PHASE DISTURBANCES C		TONE-UNCORRELATED DISTURBANCES E	F	G
METHOD OF REPRESENTATION	TONE	AMPLITUDE MODULATION	GAIN HIT OR GAIN STEP	PHASE MODULATION	PHASE HIT OR PHASE STEP	SINGLE FREQ INTERFERENCE	NOISE	IMPULSE
MATHEMATICAL	$\cos \omega t$	$(1+K \cos gt) \cos \omega t$	$(1+H) \cos \omega t$	$\cos(\omega t + m \cos Pt)$	$\cos(\omega t + N)$	$\cos \omega t + Q \cos mt$	$\cos \omega t + n(t)$	$\cos \omega t + I(t)$
TIME DOMAIN								
FREQUENCY DOMAIN								
PHASOR								
SUPPRESSED PHASOR ONLY THE DISTURBANCE IN THE PHASOR PLANE IS DISPLAYED. THE REF TONE IS SUPPRESSED	ORIGIN							

bandwidth (typically 20-300 Hz). This is called phase modulation.* Note in Figure 5 that the first sidebands of the modulated tone have an opposite sense as compared to the sidebands of an amplitude modulated tone, and that the second sidebands are AM-like sidebands. This can best be understood by considering the phasor representation. The phasor is rotated plus and minus with respect to reference. This produces a quadrature component between the reference tone and the received tone of amplitude sin Φ. It produces an amplitude variation of (1-cos Φ). The amplitude variation occurs at a double frequency; that is, as the phasor rotates from zero positively and back to zero, the amplitude goes through a complete cycle. And likewise, as the phasor rotates from zero negatively back to zero, the amplitude goes through a complete cycle. The complete mathematical expansion for a single frequency of phase jitter involves an infinite series of Bessel functions, of which the first sidebands correspond to J1 and the second sidebands correspond to J2. For the normally encountered phase modulation, the first two sidebands provide a sufficiently accurate description because of the low index of the modulation.

The Phase Hit column of Figure 5 represents before and after snapshots. It is necessary, in the frequency domain representation, to consider separately the sin wt and cost wt components of the frequency spectrum. Before the phase hit, the signal energy resides in the cos wt spectrum, and the sin wt spectrum is zero. The hit amounts to transfer of energy from the cosine to the sine spectrum. Note that for a true phase hit, the rms sum of the sine and cosine spectrums remains constant. There is no reference phase in a communication channel, thus there is no phase equivalent to a dropout. The test instrument tracks the phase of the received tone more or less slowly, and a phase hit is defined as an abrupt change with respect to the recent average phase of the received tone. Again, criteria are needed to define both the rate of change and the amplitude of the hit. Both steps (unidirectional abrupt changes in phase) and hits (phase discontinuities which are followed by a return to the starting phase) are found on typical common carrier facilities.

In suppressed phasor representation phase modulation appears as a circle arc or as a horizontal line depending upon its frequency. If the display filter passes the second sideband the result will be a circle arc, if the modulation frequency is high enough so that the second sideband is outside the filter pass band, the display will be a horizontal line. Hits produce transient excursions which, depending upon hit transition time, are essentially circle chords aimed at the hit angle. The transients are eventually suppressed by the phase lock loop which, as does the AGC loop, corrects for a step transient in nominally 1/7 second.

6. NONSYNCHRONOUS OR UNCORRELATED DISTURBANCES

Nonsynchronous disturbances are single frequency interference (SF1), steady noise, and impulse noise. Quantizing, aliasing, and sampling interval noise in PCM systems is a special case of correlated noise which previously has been lumped with random noise. With the suppressed phasor technique such noise has a characteristic pattern. Figure 6 shows a single frequency interfering tone, which, when added to the test tone, produces a phasor domain signal as shown. There is a unit length vector directly upward representing cos wt, plus the additive SF1 vector spinning around the tip of the unit vector. The amplitude of this spinning vector is the amplitude of the single frequency interfering tone relative to the tone amplitude, and the circular frequency of its rotation is the difference frequency between the test tone cost wt and the single frequency interfering tone. It is, in effect, a single sideband modulation.

Steady noise is similar to single frequency interference except that it comprises a spectral distribution of varying amplitude interfering signals. As also depicted in Figure 6, a phasor representation, there is no single, unique spinning additive vector. The instantaneous value of the output can be any place within the relatively jagged circle. The amplitude of the "circle" is a measure of the summation of the noise factors as they reinforce and interfere with each other.

Figure 6 also shows an impulse. Impulses are highly variable and usually brief, lasting only a few milliseconds. A typical signal to steady noise objective is 24 dB. A comparable signal to impulse noise objective is 5 dB. The difference is acceptable partly because of the short duration of impulse noise, and partly because hit ratios are based on rms/peak, whereas steady ratios are rms/rms. Figure 6 represents the instantaneous situation during the impulse which will typically have its energy in some band that is not necessarily symmetric about the tone, and which will not necessarily define a circle in the phasor diagram.

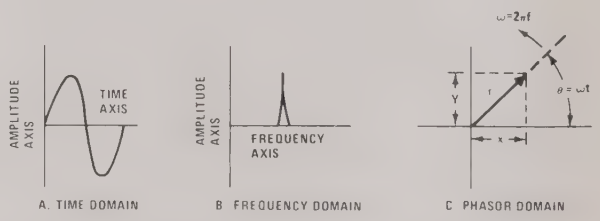


Figure 7 Representations of a Sinusoidal Tone in Three Domains

7. SUPPRESSED-TONE PHASOR DOMAIN, BACKGROUND

Suppressed-tone phasor-domain representation is a new technique for rapid display, classification, identification, and measurement of all disturbances induced on a test tone by a transmission channel.

Signals are conventionally represented in the time domain (Figure 7A), as displayed by oscilloscopes, and in the frequency domain (Figure 7B), as displayed by spectrum analyzers. Signals may also be represented in the phasor domain, and displayed on suitable instruments, such as the PB-1 VF Line Analyzer, Figure 1.

*Phase jitter is the sum of the effect of Incidental Phase Modulation and of noise within the jitter filter bandwidth on the signal phase.

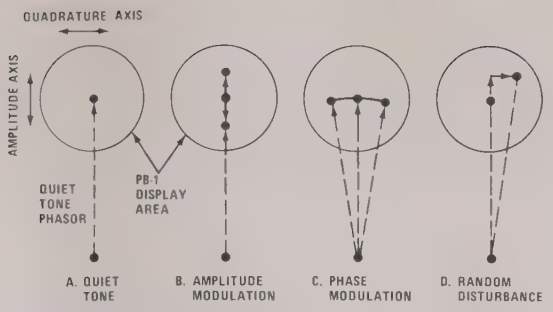


Figure 8 Suppressed-Tone Phasor Representation

In the phasor domain, a sinusoid of frequency f(Hz) is represented by a radius vector called a phasor, which hypothetically rotates about its origin at the angular velocity $w(=2\pi f)$ radians per second (Figure 7C), but which appears stationary because it is illuminated at exactly the same position in each rotation by a hypothetical stroboscope. The amplitude of the sinusoid is represented by the length of the phasor, and the phase of the sinusoid is represented by the angular position of the phasor at the instant of 'illumination'. One common 0° angle reference for phasors is the horizontal to the right of the origin (Figure 7C); another, used by the PB-1, is the vertical up from the origin (Figure 8A). Note that phasors may be represented either by the polar coordinates r(length) and θ (angle) with respect to the 0° reference, or by the rectangular coordinates which represent the projections or 'shadows' of the phasor on the in-phase axis and on the quadrature axis respectively. These shadows describe the familiar time-domain sine wave. As the phasor rotates through 360°, the sine (or cosine) wave goes through a complete cycle. When a pure sinusoidal test tone is transmitted through a voice-frequency communication channel, impairments in the channel may induce on that tone a wide range of disturbances such as noise, phase modulation, amplitude modulation, interfering tones, harmonics resulting from nonlinear distortion, and transients of various kinds. If the steady-state component of the received signal (i.e., the 'quiet tone') is displayed as a vertical phasor (Figure 8A), the disturbances (which are not stationary with respect to the tone) will add (vectorially, and on an instantaneous basis) to the tip of that phasor. The entire phasor need not be shown, because its coordinates, whether polar or rectangular, are completely defined by a point representing the location of its tip with respect to the reference axes. Since disturbances are usually much smaller in amplitude than the test tone, the tip of the resultant phasor (representing the vector sum of the steady-state received tone plus instantaneous disturbances) is normally confined to a small area around the tip of the steady-state tone phasor. This is the area that is displayed by the PB-1 in its vector mode. By suppressing the steady-state tone phasor (which contains no information about disturbances) so that the tip of that phasor is at the center of the display, only the disturbance phasors are shown. These can therefore be shown on an enlarged scale, thus increasing the resolution and accuracy with which those disturbances can be measured. The direction and amplitude of the disturbance phasors on the suppressed-tone phasor display depend on the nature and amplitude of the disturbances.

8. THEORY OF OPERATION (See Figure 9)

The mechanization employs two high-gain closed loops, an Automatic Gain Control (AGC) loop and a Phase-Lock Loop (PLL), which are interconnected to operate as a narrowband notch filter that automatically tracks and suppresses a steady-state tone. A received signal, comprising a steady-state test tone (V_r cos wt) and accompanying disturbances caused by impairments in the transmission channel under test is amplified by the AGC Amplifier so that the steady-state tone (V_{ref} cos wt) is normalized by being made equal to a reference voltage (V_{ref} cos wt) from the PLL. The normalized steady-state tone and its disturbances (which remain in scale to that tone) are fed to a Difference Amplifier and to the PLL. The PLL locks on to the tone component (V_r cos wt), and develops two orthogonal reference voltages: V_{ref} cos wt, in phase with the steady-state tone; and V_{ref} sin wt, in quadrature with the steady-state tone. The in-phase reference voltage is fed to the Difference Amplifier and to the NNN Cos wt Multiplier. The quadrature reference voltage is fed to the NNN Sin wt Multiplier.

The output of the Difference Amplifier is the normalized input signal with the normalized received tone removed, leaving only the normalized disturbances. Disturbances remaining after a test tone has been removed, suppressed, or 'notched' from a signal, are conventionally called 'notched noise'. Since the PB-1 notches the steady-state tone from the normalized signal, the remaining disturbances will be referred to as 'normalized notched noise' (NNN).

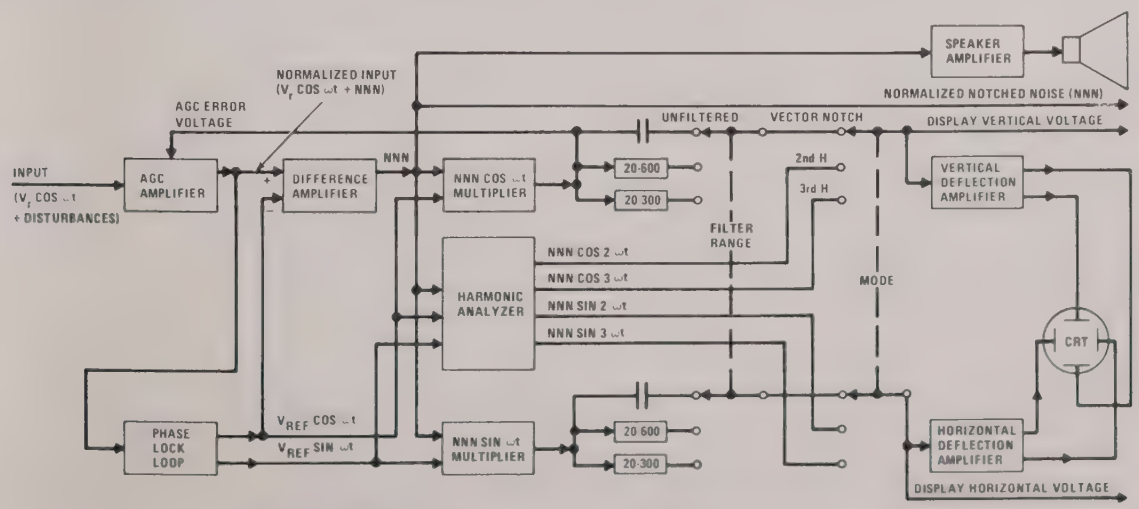


Figure 9 PB-1 VF Line Analyzer, Simplified Block Diagram

In the so-called "VECTOR NOTCH" mode the NNN is classified vectorially, i.e., in the QAM plane, with respect to the test tone. The NNN output of the Difference Amplifier is fed to the NNN Cos wt Multiplier, to the NNN Sin wt Multiplier, and through an amplifier to a loudspeaker. The NNN Cos wt Multiplier output is the NNN component in phase with the steady-state tone; this is fed, through the FILTER RANGE and MODE switches, to the CRT Vertical Deflection Amplifier.

The NNN Sin wt Multiplier output is the NNN quadrature component; this is fed, through the FILTER RANGE and MODE switches, to the CRT Horizontal Deflection Amplifier. Since these components are normalized, the corresponding CRT deflections may be measured against CRT graticule scales calibrated relative to the received test tone. The voltage NNN cos wt is also used as the error voltage that causes the AGC Amplifier to normalize the received signal so that the received tone equals the in-phase reference tone from the PLL.

The time constants of the AGC and Phase-Lock Loops are selected so that the loops operate rapidly enough to recover from transients within the conventional 1/7 second dead time interval of Hit Counters, but do not operate so rapidly that they mask Hits, Steps, or other transients.

The NNN voltage from the Difference Amplifier and the in-phase and quadrature reference voltages from the PLL are fed to a Harmonic Analyzer that develops in-phase second and third harmonic components, and quadrature second and third harmonic components, of the Normalized Notched Noise. In the second harmonic mode, the in-phase second-harmonic component (NNN cos 2wt) is fed to the vertical deflection amplifier, and the quadrature second harmonic component (NNN sin 2wt) is fed to the horizontal deflection amplifier. Similarly, in the third harmonic mode, the in-phase third-harmonic component (NNN cos 3wt) is fed to the vertical deflection amplifier, and the quadrature third harmonic component (NNN sin 3wt) is fed to the horizontal deflection amplifier.

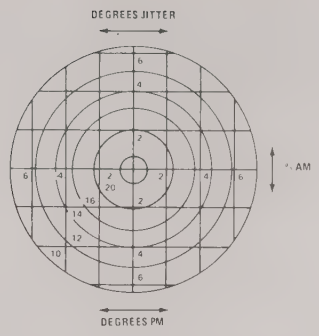


Figure 10 Graticule, Circles Calibrated in Relative dB

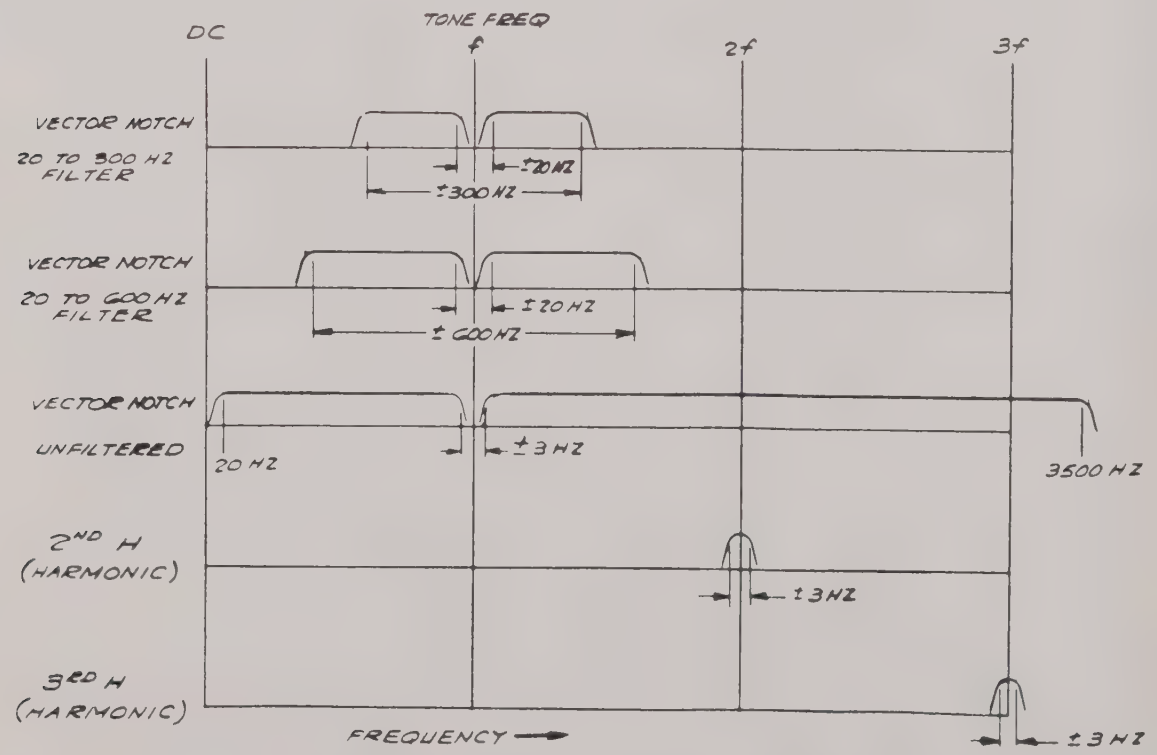


Figure 11 Bandwidth of PB-1 Display in Various Modes

The instantaneous disturbance, as classified in the QAM plane is measured against a graticule which has three scales, Figure 10. The quadrature (horizontal) scale is graduated in degrees of phase jitter. The in-phase (vertical) scale is graduated in % AM, and the polar (circular) scale is calibrated in dB relative to the received tone. Scale Multiplier (or adder for the dB scale) is switch selectable.

The acoustic notched noise output is informative because the tone is attenuated by more than 50 dB and hence does not override the characteristic sounds of the impairments. Harmonics, SFI, tone and modulating tones may be clearly distinguished when they are 50 dB down. Transients too are well delineated. Modulation hits (phase, gain, dropouts) "pull" the tracking loops causing the tone to "leak" through during loop recovery. The result is a sonar-like "ping". Impulse hits do not pull the loops and are therefore audibly reflected as a pop, click, or momentary noise burst. Short duration phase or gain hits also do not have time to pull the loop and so sound like impulse hits but cause excursions at a fixed deflection angle (horizontal or vertical).

That segment of the VF channel bandwidth which is examined in the several operating modes is indicated in Figure 11. The 20 to 300 Hz filter corresponds to the Bell and CCITT jitter filter. The 20 to 600 Hz filter is a frequency apeture which more closely approximates that of synchronous modems (using 1700 Hz as the tone frequency). The unfiltered mode permits examination of the entire voice band. The two harmonic filters are narrow to permit examination of harmonics in the presence of a higher level of background noise.

9. VECTOR NOTCH MODE FACILITY ANALYSIS

Diagnostic and measurement capabilities are illustrated in Figure 12 to 29. All data is obtained using a 1004 Hz test tone at -16 dBm, with the instrument in the vector mode, with the speaker broadcasting with notched noise. The bandwidth of the display is determined by one of three filters, (20-300 Hz), (20-600 Hz0 and UNFILTERED. The left-hand photograph of each pair was taken with the (20-300 Hz) filter, and the right-hand photograph of each pair was taken at UNFILTERED. The (20-300 Hz) filter provides displays compatible with conventional Bell System and CCITT Phase Jitter test sets. However, this filter limits the disturbance bandwidths displayed to those in the sidebands 20 to 300 Hz below the test tone and 20 to 300 Hz above the test tone. In contrast, the UNFILTERED mode provides displays (right-hand photos) showing the entire spectrum of disturbances from 30 to 3500 Hz, with a notch bandwidth so narrow that disturbance components within 1 Hz of the test tone frequency may be observed.

In the detection of modulation impairments, the notched noise is translated downward in frequency by the amount of the test tone and is thus centered at dc with the lower sideband folded back onto the upper sideband. This is accomplished by an internal modulator which multiplies the notch noise by the reference tone. At the same time, the same modulator translates the notched noise upward by the amount of the tone frequency, because the modulator produces the sum as well as the difference frequencies of its two inputs. The dc-centered sidebands produce the 20 to 300 Hz picture, the upper sidebands being eliminated by the filter. The dc-centered plus the double-tone-frequency sidebands produce the UNFILTERED mode picture. Note that modulation impairments show up two ways in the UNFILTERED mode. This is really a reflection of the instrumentation used to reduce them to a display and not a picture of what is actually happening to the tip of the tone factor. It is useful because it 'flags' or calls attention to the modulation impairments, allowing them to be observed even in the presence of a larger amount of noise. The same thing is true in amplitude jitter where the circles are vertically oriented. For Transient modulation impairments, the circles grow or expand to one side or the other depending upon the hit direction and its dynamics. In low frequency modulation phenomena, the circles oscillate back and forth or up and down at the modulation frequency. Figures 12 through 17 show various types of non-tone-correlated disturbances. Figures 18 through 21 show various types of tone-correlated phase disturbances. Figures 22 through 25 show various types of tone-correlated amplitude disturbances.

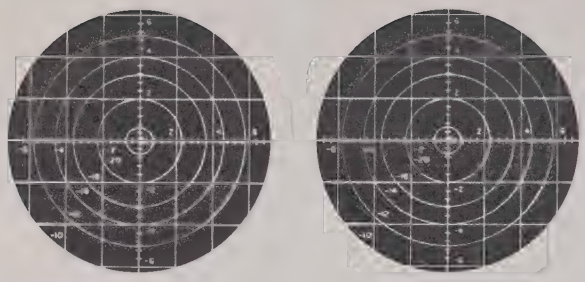


Figure 12

QUIET TONE: All disturbances more than 50 dB below tone level.
Display: Spot at origin (tone phasor tip stationary).
Sound: Inaudible

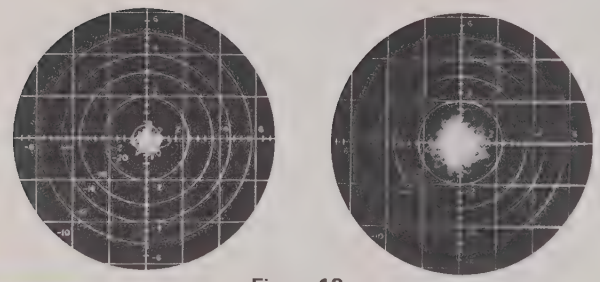


Figure 13

STEADY NOISE: White Noise 25 dB below tone level.
Display: Spot moves in random manner around origin. Note that because of wider bandwidth, the UNFILTERED display passes more noise.
Sound: Steady hiss

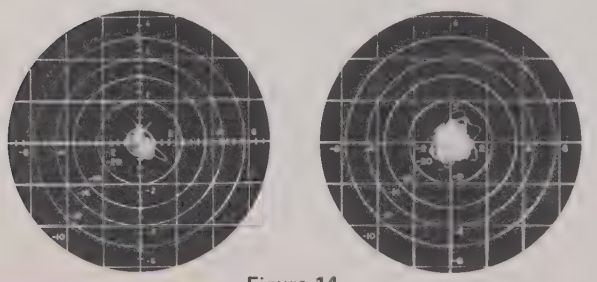


Figure 14

STEADY NOISE PLUS IMPULSE: White Noise 25 dB below tone level, plus single impulse 10 dB below tone level. The impulse shown, which has an 800 to 2,300 Hz flat spectrum, is representative of impulses occurring on VF channels.
Display: Transient deflection at random angle. The steady White Noise typically does not 'modulate' or widen the impulse transient deflection because the impulse is too short to 'pull' the AGC or Phase-Lock Loop. See Phase Hit (Figure 7-4) and Gain Hit (Figure 7-7) for contrast.
Sound: Steady hiss with 'pop' at time of impulse.

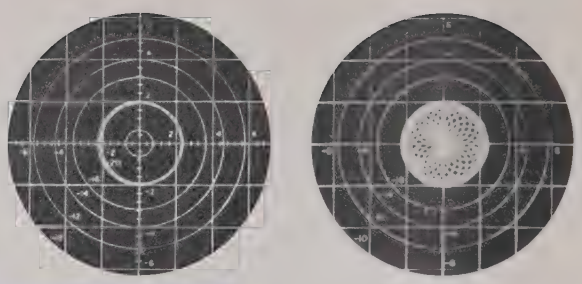


Figure 15

SINGLE-FREQUENCY INTERFERENCE (SFI): 10% SFI (i.e., 20 dB below tone level) at 1100 Hz.
Display: Spot traces circle about origin as SFI phasor spins around tip of tone phasor at difference frequency of 100 Hz (=1100 Hz-1000 Hz). The difference frequency is within the passband of the 20 to 300 Hz filter.
Sound: 1100 Hz tone.

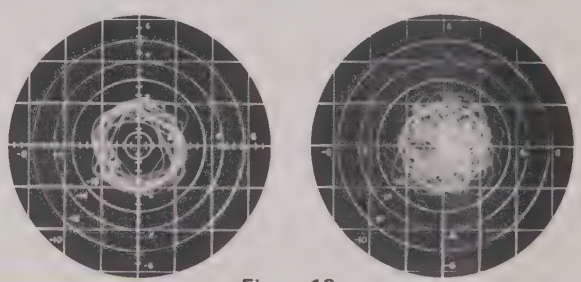


Figure 16

SFI PLUS STEADY NOISE: 10% SFI (20 dB below tone level) at 1100 Hz, plus White Noise 25 dB below tone level.
Display: Characteristic doughnut shape as SFI circular trace is widened by noise.
Sound: Steady hiss plus 1100 Hz tone.

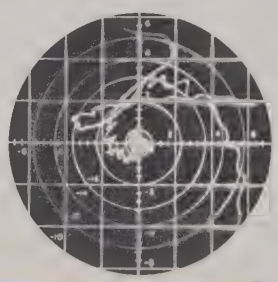


Figure 17

FREQUENCY HIT PLUS STEADY NOISE: White Noise 25 dB below tone level, plus a single 2-Hz Frequency Hit.
Display: Spot deflects and then spirals back toward origin as the Phase Lock Loop acquires and tracks the new frequency. Trace is modulated by the noise.
Sound: Steady hiss with loud tone-frequency 'ping' at time of hit.

Figures 18 through 21 below show various types of tone-correlated phase disturbances

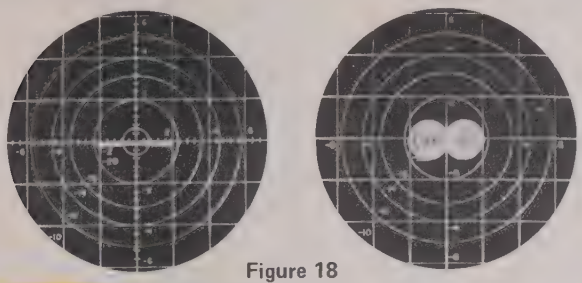


Figure 18

PHASE MODULATION: 10° Phase Modulation at 100 Hz.
Display: Spot traces a nearly horizontal circular arc. Note that the UNFILTERED display passes upper PM sidebands. See comments on Filtered and Unfiltered Displays on Page 6. The diameter of the circles is PM magnitude.
Sound: 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz tone).

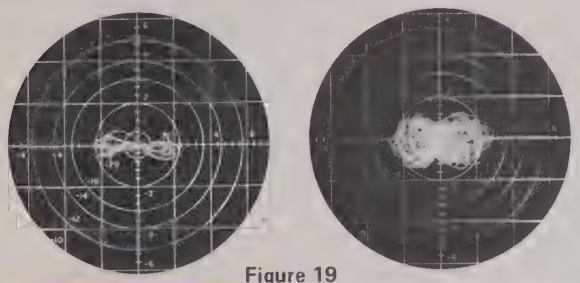


Figure 19

PHASE MODULATION PLUS STEADY NOISE: 10° Phase Modulation at 100 Hz plus White Noise 25 dB below tone level.
Display: Horizontal dispersion exceeds vertical dispersion.
Sound: Steady hiss plus 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz).

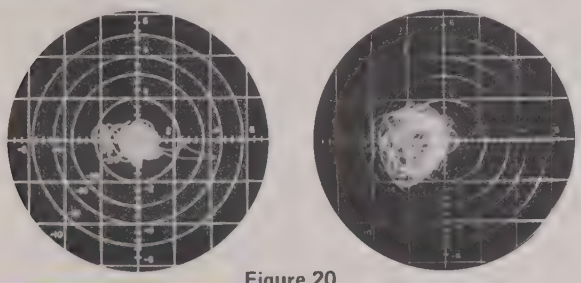


Figure 20

PHASE STEP PLUS STEADY NOISE: 10° Phase Step with 4 millisecond rise time, plus White Noise 25 dB below tone level.
Display: Phase transient causes essentially horizontal deflection of spot. Phase Lock Loop moves to the new phase with a recovery time of 1/7 second. During this recovery time, any noise present on the signal vertically modulates or widens the essentially horizontal transient excursions. The UNFILTERED display shows momentary appearance of a sideways-oriented circle for the duration of hit and the recovery time of the instrument. Its diameter is the hit magnitude.
Sound: Steady hiss with tone-frequency 'ping' at time of hit.

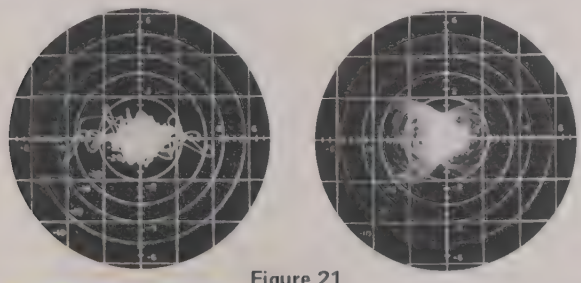


Figure 21

PHASE HIT PLUS STEADY-NOISE: 20° Phase Hit with 4 millisecond rise time and 100 millisecond duration, plus White Noise 25 dB below tone level
Display: Same as Figure 7-3, except that horizontal excursion is symmetrical about origin The UNFILTERED display circle alternately appears to the left and right at a rate dependent upon the hit duration and rise time
Sound: Steady hiss with tone-frequency double 'ping', one at leading edge and one at trailing edge of hit. This double ping can be audibly resolved for Phase Hit durations as short as 40 milliseconds.

Figures 22 through 25 below show various types of tone-correlated amplitude disturbances

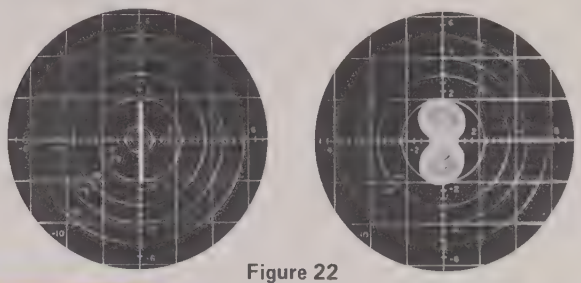


Figure 22

AMPLITUDE MODULATION: 10% AM at 100 Hz.
Display: Spot makes vertical trace symmetrical about origin. The UNFILTERED display passes the upper AM sidebands; see comments on Filtered and Unfiltered Displays on Page 6. The diameter of the circle is the AM.
Sound: 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz tone).

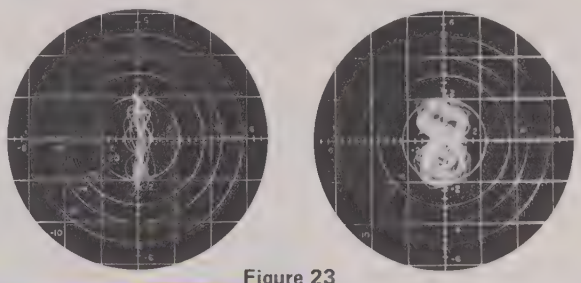


Figure 23

AMPLITUDE MODULATION PLUS STEADY NOISE: 10% AM at 100 Hz, plus White Noise 25 dB below tone level.
Display: Vertical dispersion exceeds horizontal dispersion.
Sound: 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz tone) plus hiss

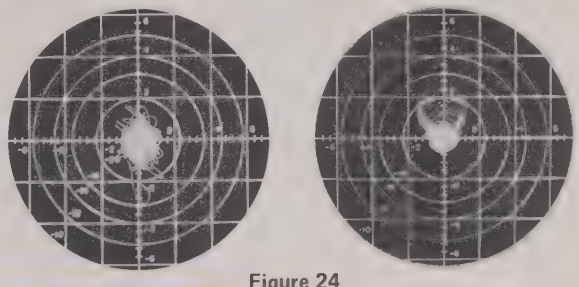


Figure 24

GAIN HIT PLUS STEADY NOISE: 2 dB Gain Hit with 4 millisecond rise time and 100 millisecond duration, plus White Noise 25 dB below tone level.
Display: Amplitude transient causes essentially symmetrical vertical excursion. Depending on size of hit and LEVEL ADJ setting, the DO NOT READ lamp may go on momentarily as the AGC loop moves to new level with a recovery time of 1/7 second. The UNFILTERED display circle alternately appears up and down at a rate dependent upon the duration and rise time of the hit.
Sound: Steady hiss with tone frequency double ping, one at the leading edge and one at the trailing edge of the hit. This double ping can be audibly resolved for hit durations as short as 40 milliseconds.

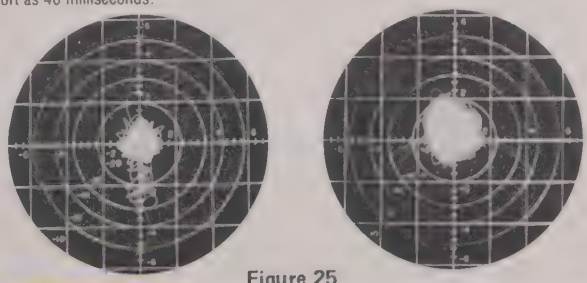


Figure 25

DROPOUT PLUS NOISE: 12dB, 10 millisecond fast dropout plus White Noise 25 dB below tone level
Display: Deep vertical drop. DO NOT READ lamp goes on and remains on until after end of dropout
Sound: Noise hiss, with loud, brief tone-frequency 'ping'. As dropouts get shorter, the ping becomes closer to the 'pop' noise of an impulse. At 2 milliseconds dropout duration the tone component of the noise is barely distinguishable

Figure 26

Figure 26
SECOND HARMONIC DISTORTION: Second Harmonic Distortion 30 dB below tone level.
Display: Four-lobe cloverleaf pattern, which may rotate continuously in the presence of frequency translation, move through limited angles in the case of low frequency jitter, or expand and contract in the presence of harmonic hits.
Sound: Distinctly audible second harmonic of test tone.

Figure 27
SECOND HARMONIC DISTORTION PLUS NOISE: Second Harmonic Distortion 30 dB below tone level, plus White Noise 30 dB below tone level.
Display: Same as Figure 8-1, with dispersion caused by noise.
Sound: Audible second harmonic of test tone over noise hiss.

Figure 27

Figure 28
THIRD HARMONIC DISTORTION: Third Harmonic Distortion 30 dB below tone level.
Display: Three-lobe cloverleaf pattern.
Sound: Audible third harmonic of test tone.

Figure 29
THIRD HARMONIC DISTORTION PLUS NOISE PLUS PHASE JITTER: Third Harmonic Distortion 30 dB below tone level, plus White Noise 30 dB below tone level, plus 10° Phase Jitter.
Display: Three-lobe cloverleaf pattern plus noise smear plus phase jitter circle pattern.
Sound: Audible third harmonic of test tone over noise hiss.

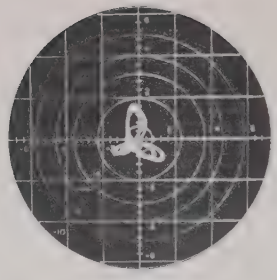


Figure 28

Figure 29

10. DISTORTION ANALYSIS, UNFILTERED VECTOR NOTCH MODE

Second and Third Harmonic Distortion are visible in the UNFILTERED vector mode, but (for test tones of 800 Hz and higher) are out of the passband of the 20-300 Hz and 20-600 Hz filters. Figures 26 through 29 are thus for the UNFILTERED vector mode only. Because harmonics of the test tones are coherent with that test tone, they form cloverleaf patterns that indicate the order of the harmonic. Pure second harmonic forms a four-lobe cloverleaf pattern; pure third harmonic forms two nearly coincident three-lobe cloverleaf patterns which is actually a six-lobe pattern folded over.

11. DISTORTION ANALYSIS, HARMONIC MODES

Figure 31 is a typical second harmonic or third harmonic display in the harmonic modes. The deflection amplitude is a measure of the distortion magnitude, and the deflection angle is a measure of the phase intercept distortion of the channel. Since phase intercept distortion is an uncontrolled parameter, the deflection may be in any direction. It is therefore usually convenient to read the deflection against the circular (POLAR dB) scales. In the most sensitive scale position, the inner circle corresponds to a separation of -50 dB; i.e., the harmonic level is 50 dB below the tone level.

Harmonic distortion remains in-band only when it occurs at baseband appearances of the signal. Once a channel has been multiplexed distortion products fall out of band. Figure 30 shows the entry points of harmonic distortion at a VF channel having voice appearances only at each end.

When frequency translation is present, the phase intercept distortion angle changes continuously at a constant rate and the spot moves in a circular path, as shown in Figure 31B. The impairment location causing it is shown in Figure 30. Note that the Receive Terminal, the frequency of the distortion content, cos (2wt + st), differs from twice the frequency of the fundamental, cos 2 (wt + st) by the amount st. This is the equivalent of an SFI input at a beat frequency of st. When an additional second harmonic distortion, K_r cos (2 wt + 2 st) is introduced at the Receive Terminal, after the frequency translation, it is distortion of the received frequency; it is thus exactly double the received frequency and produces a stationary spot. In Figure 31C, note that the circle radius (K_t) corresponds to the distortion which occurs ahead of the frequency translation; the offset (K_t) of the center of the circle corresponds to the distortion which has occurred after the frequency translation; and the rate at which the circle is traversed by the spot is a measure of the frequency translation. The foregoing analysis may be extended to third harmonic distortion.

There may be multiple frequency translation sources as well as other phenomena which cause variations in the phase intercept distortion angle. Phase hits cause intermittent angular motion of the spot. Phase modulation causes oscillatory angular motion of the spot. Filters limit the display bandwidth in the harmonic modes so that only low-frequency jitter can be observed. There may also be harmonic amplitude hits, usually involving PCM carrier, which cause radial motion of the spot. There are normally multiple distortion sources although in a trouble situation, usually one will predominate. These phenomena may occur at any voice appearance in the transmission path, with unpredictable phase shift between their point of generation and the final output. The result is spot motion in random directions. The operational significance of the above is that if the distortion spot displays high mobility it is an indication that the channel will have trouble passing data.

12. PHASE INTERCEPT DISTORTION

The time delay for any frequency component passing through a transmission medium is the slope of the line joining that point on the curve with the origin on a phase vs. frequency plot. One condition required for undistorted trans-

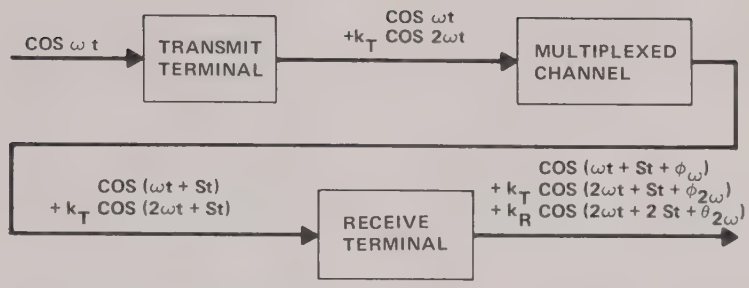

COS ω t
TRANSMIT TERMINAL
COS ωt +k_T COS 2ωt
MULTIPLEXED CHANNEL
COS (ωt + St) + k_T COS (2ωt + St)
RECEIVE TERMINAL
COS (ωt + St + φ_ω) + k_T COS (2ωt + St + φ_2ω) + k_R COS (2ωt + 2 St + θ_2ω)

Figure 30 Sources of Second Harmonic Distortion (Simplified Analysis)

Figure 31 Typical Displays in the 2nd H and 3rd H Modes

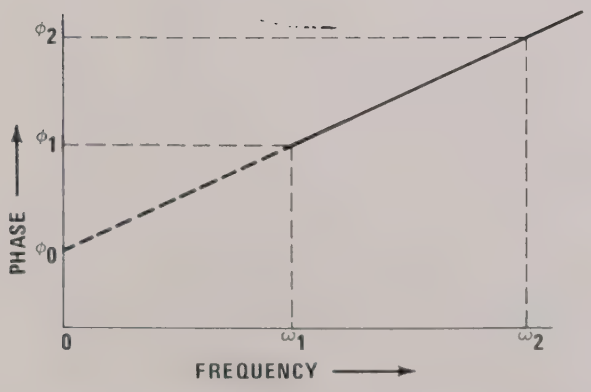


Figure 32 Definition of Phase-Intercept Distortion

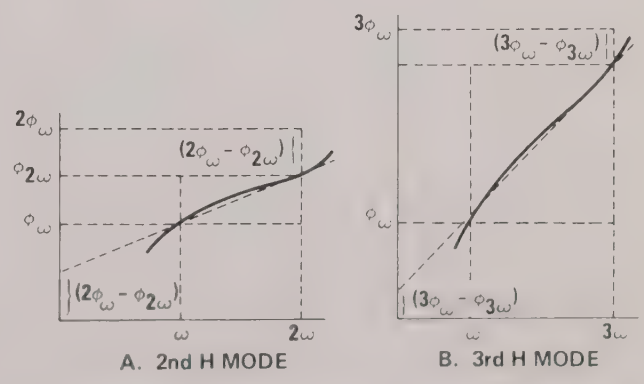


Figure 33 Quantities Measured in 2nd H and 3rd H Modes

mission of a complex wave shape is that the phase vs. frequency curve (plotted in linear units, and extrapolated down to DC) be a straight line passing through the origin. This is the response corresponding to a pure time delay. The slope of this line is the time delay, t. Dimensionally $\Phi/w = t$; Radians/(Rad/Sec) = Sec. There is no time domain wave-shape distortion because all frequency components have the same time delay and therefore arrive in the seme relative phase at the far end as they leave at the near end.

Note that a perfectly linear phase vs. frequency curve (zero envelope delay distortion) is not a sufficient condition for low baseband distortion because (Figure 32) the component of frequency w_1 has a time delay Φ_1/w_1 which is different from that of the w_2 component, Φ_2/w_2. This distortion is a result of the intercept angle Φ_0, of the extrapolated phase vs. frequency curve, at zero frequency. This is known as the phase intercept distortion. It is an uncontrolled parameter in most communications systems.

The angular displacement of the spot for either second or third harmonic distortion measurement is a measure of the phase intercept distortion. In the mechanization of the instrument, the received tone, cos $(wt + \Phi_w)$ is tracked. It is then doubled, i.e., cos $(2wt + 2\Phi_w)$. The phase and amplitude of the second harmonic cos $(2wt + \Phi_{2w})$ is plotted with respect to the double frequency tone as a reference. Referring to Figure 33 which is a phase vs. frequency plot, the phase difference between cos $(2wt + 2\Phi_w)$ and cos $(2wt + \Phi_{2w})$ is $(2\Phi_w - \Phi_{2w})$. This is the deflection angle of the harmonic distortion spot. It is also the phase intercept distortion based on measurement at frequencies w and 2w. A similar observation is true with respect to the third harmonic.

Angular motion of the harmonic spot corresponds to changes in phase intercept distortion. This motion will always be along an arc of some circle for a given distortion source and the phase intercept distortion due to that source. However, a multiplicity of distortion sources may exist in a transmission channel relative to a multiplicity of phase intercept distortion sources. The case of frequency translation described above is commonly encountered.

The frequency response of this measurement in the mechanization is limited by the filter bandwidth in the deflection amplifier. This must be narrow to keep the erratic spot motion induced by background noise below acceptable limits relative to the lowest harmonic distortion measurement threshold (50 dB below signal level). Where it is desired to study the phase intercept distortion, a harmonically rich signal can be transmitted. This raises the harmonic level well above the normal noise level and permits the filter bandwidth to be increased.

13. IMPLICATIONS OF THE SUPPRESSED-TONE PHASOR-DISPLAY TECHNIQUE

The single most significant fact about the suppressed-tone phasor-display technique is that it permits a meaningful display of all impairments over a wide VF spectral range at one time. Such a presentation in the time domain or the frequency domain is not meaningful because the information is not comprehensible. Early users of the PB-1, primarily Bell System DATEC engineers, were quick to notice that, using it as the translating device between facility and craftsman, not only do relationships between presently defined impairments become clear, but previously unobserved impairments become apparent. Impairments are shown in real time as they actually happen, so that it is possible to characterize a facility in a matter of minutes. In the VECTOR NOTCH, UNFILTERED mode, the display includes the entire voice band, except for the notch region within ± 1 Hz of the test tone. The information is classified in the QAM plane, a classification which shows phase relationships between impairments and tone more clearly than any other measurement or display technique. Phase relationship information pinpoints fault location in a facility because it permits noise, modulation, and harmonic distortion disturbances to be resolved by inspection. As a result, the instrument has quickly become a 'microscope' for the examination of facility performance from an entirely new and informative viewpoint.

a. LIMITATIONS OF EXISTING PRACTICE

Conventional transmission channel instrumentation reduces tone impairments to sets of numbers. To accomplish this the impairments are filtered, detected by one of a variety of detectors, e.g., average value, rms, quasi-rms, peak, etc., time averaged, and displayed as a numerical result. Transient phenomena are also monitored in this pattern. The time-averaging interval typically becomes 15 minutes, and the detector a presetable analog threshold level detector with artfully defined criteria for hit duration, hit rise time, and hit interval. The problems with such measurements are as follows:

1. It is virtually impossible to convert two-dimensional time-varying and/or random quantities into a set of numbers of any reasonable set size. Information is necessarily lost in the process. The present 12 to 16 number set of line parameter readings falls short of describing all line conditions. Moreover, "comprehension" of this set of numbers, in the sense of fully integrating their meaning, requires a sophistication which is rare at craft level.

2. Any set of rules for converting the information into numbers, no matter how artfully chosen, can represent only what is generally the case for known phenomena. Exceptional cases and unrecognized impairments are frequently hidden. It is accepted that the results will be misleading in some small percentage of cases. Nevertheless exceptions and 'new' impairments always come as a surprise, and they result in those occasional long-duration and costly maintenance efforts which continue interminably until someone recognizes the hole in the definition through which the impairment has slipped.

3. A costly characteristic of the presentation of purely numerical results is obsolescence. From time to time new impairments are defined. Further the classification rules for existing impairments are changed, as a result of new data set requirements, new tariffs, new facilities, and/or discovery of new phenomena. When this happens, existing test equipment, which mechanizes existing rules, becomes obsolete. The PB-1, in its unfiltered vector mode, imposes virtually no limitations on the impairments displayed. The rules are "in the eye of the beholder".

b. NOTCHED NOISE, AN EXAMPLE

As an example of the effect of instrument mechanization rules on information content, consider C-message-weighted notched noise. Notched noise is what remains after the tone is removed. It includes additive noise, modulation impairments, and harmonic distortion impairments. Because it includes all disturbances, notched noise is the single most meaningful conventional existing impairment parameter for evaluation of facility/modem compatibility. This has been recognized in the Bell System

"D" tariff, which essentially specified rms notched noise and nonlinear distortion.

RMS noise is a measure of the energy content of disturbances. It is the all-important quantity when rms detectors, such as ears, are involved. As channel bandwidth is used more effectively however, the requirements on disturbances become more stringent. For synchronous modems, making several thousand multi-state analog threshold decisions per second, disturbance sensitivity is more closely measured by instantaneous (peak) noise rather than by rms noise. Further, the sensitivity of synchronous modem error rates to modulation impairments is determined by the modem encoding scheme; e.g., phase-encoded modems are only marginally susceptible to amplitude disturbances.

The typical notched noise measurement is C-message weighted, a weighting which discriminates heavily against power line frequencies. The signal is weighted by a specific bandpass filter. The test tone is removed with a narrow band-reject (notch) filter. The remainder is detected with an rms or quasi-rms detector, the output of the detector is averaged with a specified fractional-second-averaging time constant, and the result is displayed as a number. Since the number is in dBm or dBrn, a logarithmic element is included. The following information is removed by the above set of rules:

1. Crest Factor. This is the ratio of peak to rms noise. It is highly waveshape dependent. For white noise on a VF channel this factor is 8 or 9 to 1, for a sine wave it is 2.8 to 1. The 'spikiness' of the noise is completely masked in an rms measurement.

2. Phase Relationship of Impairments to Tone. Phase modulation or amplitude modulation may, depending upon the nature of the modem encoding scheme, be less harmful than random noise.

3. Harmonic Relationship of Impairments to Tone. Certain harmonics are more significant in data impairment than their contribution to rms noise.

4. Phenomena near the tone frequency, such as low frequency modulation impairments, will be attenuated or eliminated because of the bandwidth permitted in the notching (band reject) filter.

However, if the noise is 'typical' in character, i.e., the large majority of cases, the measurement result is valid for establishing facility/modem compatibility. If the noise is unusually 'spikey', if low frequency modulation is present, if an SFI tone near the modem clock frequency is present, or if the impairment is entirely in the 'wrong' direction (e.g., phase modulation on a facility which is to be used with a phase-cndoded modem), the line may not move data. On the other hand if the impairment is primarily SFI remote from the modem clock frequency, or is primarily in the 'right' direction (e.g., amplitude modulation on a facility which is to be used with a phase-encoded modem), the measurement result may be unduly conservative.

c. NEW INFORMATION

The suppressed-tone phasor-display technique provides two new kinds of information. One of these is information about defined phenomena which is rejected by conventional instrumentation because of the mechanization rules. This includes phenomena such as:

1. Phase Jitter. Because it was 'discovered' as a problem after the advent of vestigal-sideband and phase-enclded modems, phase jitter is not a voice-technology-based measurement; as a result, it is defined on a peak to peak basis. However, prior to the existence of suppressed-tone phasor-domain measurement it was not possible to resolve phase modulation and the effects of noise on phase. These quantities were therefore lumped and called phase jitter. In order to minimize the effects of noise on the reading, the bandwidth of impairments examined was restricted to the region between 20 and 300 Hz around the test tone.

As might be expected, due to the natural perversity of things, significant incidental phase modulation exists outside this range. Recently the problem of incidental PM below 20 Hz has surfaced, potentially obsoleting existing jitter sets. Jitter set manufacturers, including ourselves, are offering modification kits, i.e., patched-up units which will suffice until the next exception is "discovered". It is already clear, from real time examination of low frequency jitter with the PB-1, that none of the instrumentation goes low enough in frequency. This appears to be the result of a mechanization problem, the existing phase lock loops limit the low frequency response. This difficulty has been circumvented with the PB-1 by measuring not only the magnitude but the frequency of the jitter, i.e., counting the number of cycles in 5 or 10 seconds. This permits application of a correction factor when the jitter is below 3 Hz, where the meter displays roll of significantly, i.e., a significant fraction of low frequency jitter cases.

A more subtle impairment is that of incidental modulation at frequencies higher than the test tone. The lack of sideband symmetry, due to foldback of the lower sidebands, makes this condition virtually impossible to recognize with instrumentation other than phasor domain instruments. With the PB-1 in the unfiltered mode there is no confusion except for a narrow band of modulation frequency around the tone frequency and a second narrow band around the second harmonic of the tone frequency. High frequency modulation is considered to be a relatively rare problem or is not considered at all. In this respect it resembles other impairments which did not "exist" when they could not be identified.

2. Notched Noise. See discussion above.

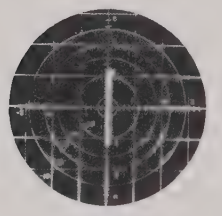
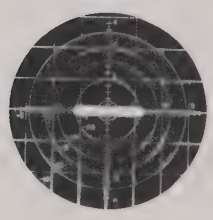
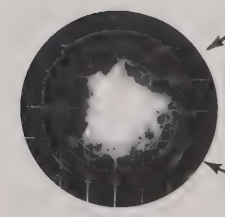
3. Transient Phenomena. This is perhaps the least defined area of all. It is necessary to define rise time, duration, interval, and phase coherence (phase hits and gain hits are phase coherent: impulse hits are not) in order to 'count' a hit. These quantities vary continuously in the real world. Hits which are below threshold or are too slow in transition, too brief, or occur too soon after previous hits are ignored. For any of these reasons, either of two hits which differ only slightly may be counted while the other hit may be ignored.

4. Amplitude Jitter. Not now routinely measured.

The second new kind of information, which is associated with the harmonic modes, is the measurement of phase intercept distortion. This is another one of those normally unmeasured quantities which characterizes a significant fraction of the 'mystery' problems, i.e., channels which meet published requirements but which will not pass data.

14. DISCUSSION OF ACCURACY

It has been suggested that the suppressed-tone phasor domain technique is less accurate than conventional measurement techniques. One perspective on this matter is suggested by the following discussion of notched noise in which five "pure" impairments, identical in rms value, are characterized in peak-to-peak and in phasor domain terms. Consider a holding tone of 1004 Hz, 0 dBm (600 ohms) in the presence of below-tabulated steady-state impairments. The notched noise is as indicated:

IMPAIRMENT	PEAK TO PEAK MILLIVOLTS	RMS VALUE	PHASOR DOMAIN REPRESENTATION
Single Frequency Interference	69	-25.0 dB	
2nd Harmonic	69	-25.0 dB	
Amplitude Modulation	98	-25.0 dB	
Phase Modulation	98	-25.0 dB	
White Noise	220	-25.0 dB	

Noise photograph - shorter exposure, to delineate peaks. Although peaks are faint in photograph, they are clearly visible in the live display.

All Photos Taken At Same Sensitivity

The above impairments are different in character. They are the result of malfunctions in different parts of the facility, and they are entirely different in their effects on high speed data. The only thing they have in common is their C-message weighted notched noise readings which agree with each other to within 0.1 dB, i.e., the conventional technique describes these highly diverse phenomena identically.

Which is the more "accurate" measurement of the impairments, the phasor domain presentation or the rms reading? Clearly, measurement "accuracy" must be considered in the light of measurement purpose. If a facility is being checked for its behavior while through-putting information for rms detectors, such as ears, or for meeting an rms-defined index requirement, the conventional technique provides more accurate information. If the purpose of measurement is to find out what is going on for facility diagnostics, or to classify a facility's performance relative to instantaneous value detectors such as modems, then phasor domain measurements are more "accurate".

The confusing factor is noise. In the presence of noise the phasor domain display provides results which are harder to "read". This happens because the impairment itself is less well defined, and the reflection of this fact in the display is not a weakness but a strength. The conventional technique reduces this same poorly delineated information to a well delineated number via filtering, detection, and time averaging. The experienced craftsman will try to read through the time-averaged technique by taking into consideration the "liveliness" or "jumpiness" of the meter reading. In fact the only significant objection to digital readouts remains their lack of suitability for estimating the center value and spread of "noisy" readings.

A discussion similar to the above can be developed for transient phenomena (hits). Here the problem is even more complicated because the mechanization for counting requires not only magnitude but phase correlation, duration, dead time, and rate of change definitions to establish what will be counted and what will not. Such definitions provide a large continuum for operation of Murphy's Law phenomena.

The suppressed-tone phasor domain technique can be used to generate highly reproducible results. Consider, illustratively, the following possibilities:

1. The use of memory display to "paint" a time record of the peak impairments over a specified period (accompanied by a photograph or a recording for a permanent record).

2. Use of an event triggered memory display with analog delay to capture an accurate record of transients (also accompanied by a photograph or a recording for a permanent record).

3. Graticule overlays which block the display in the facility's "go" region so that any visible trace is an alarm condition.

However the next step in extension of the technique involves facility performance definitions, thus its direction must await definition by an entity with industry-wide stature such as AT&T or CCITT.

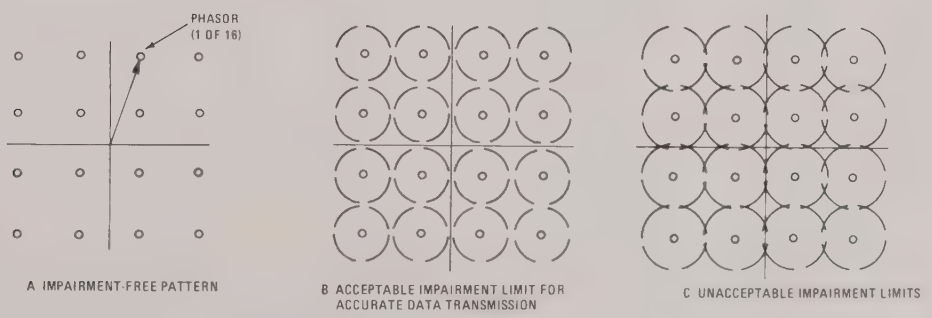


Figure 34 Decision Space Diagrams

15. NON-STANDARD APPLICATIONS

In addition to its fast and informative facility diagnostic capability the technique lends itself to a variety of applications which are less obvious. Some of these are described below.

a. GO/NO-GO EVALUATION OF LINE-MODEM COMPATIBILITY

High-speed digital data is transmitted over voice-frequency channels by synchronous modems employing phase and/or amplitude modulation of audio-frequency carriers or 'clocks'. The receiving modem 'recovers' the clock frequency from the transmitted signal; i.e., synchronizes to that clock frequency. Relatively small line impairments can cause errors in such modems; large line impairments can cause momentary loss of synchronization.

A synchronous modem transmits N bits of binary data per cycle of a clock frequency by sending one of 2^N encoded states of phase and/or amplitude modulation of that clock frequency, and changing the state once each clock cycle. For example, 16 possible states of the clock frequency may be represented by 16 phasors, as shown in Figure 34A. This type of coding is called QAM, denoting an encoding scheme combining both Quadrature and Amplitude Modulation. The entire area of Figure 34A represents the modem 'decision points', the 'constellation' or 'eye' pattern of 'decision points' represents the locations of the tips of the 16 phasors.

Line disturbances occuring at any instant during transmission of any phase-and-amplitude-modulated signal will add instantaneously and vectorially to that signal, shifting the tip of the phasor being transmitted at that instant, so the receiving modem will not see the 16 stationary points of the constellation pattern, but will see smeared areas around the theoretical points. The receiving modem can operate without error only if adjacent smeared areas do not overlap. As shown in Figure 34B, it is possible to define a geometric figure bounding the maximum permissible area within which errors will not occur. Disturbances causing overlapping smears, as in Figure 34C, will cause errors. Note that the permissible area must frequently include an allowance for harmonic distortion which is measured separately, and an allowance made for the phasor tip smear resulting from static line impairments such as gain and envelope delay distortion.

When a test tone is transmitted over a voice-frequency channel, line disturbances will add vectorially to the tip of the received tone phasor and smear that tip over an area, in exactly the same way as they would smear the tips of the 16 QAM phasors over 16 areas in the modem decision space. If the received tone is examined by a Suppressed-Tone Phasor Domain Line Analyzer, the steady-state tone is suppressed so that (in the VECTOR NOTCH mode) the disturbances can be displayed on an expanded basis. This is equivalent to continuous high-resolution examination of a single modem decision point. It can immediately be determined whether the line disturbances remain within the permissible area (GO condition) or extended beyond the permissible area (NO-GO condition). The PB-1 views all the instantaneous components of peak noise, thereby identifying not only disturbances which have been classified and are now measured by conventional test equipment, but also disturbances that have not yet been classified, and which are now ignored, even though they affect modem performance.

Because the frequency content of a modem signal may extend beyond one octave, and because harmonic distortion modifies the decision space, the line-evaluation procedure should include measurements of 2nd and 3rd harmonics. Measurement of the in-phase and quadrature components of disturbances, and the harmonic distortion, defines line performance with respect to modem requirements.

b. EVALUATING DUAL DIAL BACKUP LINES

As a corollary of GO/NO-GO line evaluation capability, the technique can be used to simplify and expedite the procedure of establishing a two-way Dial Network backup for private or leased lines between a near terminal and a marginally-attended or unattended far terminal, by reducing the problem from that of simultaneously finding two acceptable lines at each dialing to that of finding one acceptable line at each dialing.

When either or both of a pair of private or leased lines fails to transmit data satisfactorily between a near or local terminal and a far or remote terminal, it is common to use the Dial Network as a backup, by dialing two lines between the terminals for full duplex operation. To be certain that the two backup lines are usable in the intended directions of use, they must be checked out in those directions. Assuming that the means of verifying good lines is at the near terminal, the lines are looped back at the far terminal and digital data (in the case of digital loopback) or a test tone (in the case of analog loopback) are sent around the loop from and to the near terminal. If the loop-around signal is not satisfactory, two new lines are dialed and the test is repeated, until a satisfactory loop is obtained. Note that two lines must be rejected if the loop is not acceptable, even though one of the lines may be good. This necessitates dialing and testing until two simultaneously acceptable lines are found.

The go/no-go phasor approach requires that only one satisfactory line be found at a time, as follows. The far-end transmit line is dialed and a tone is sent along this line to a PB-1 at the near end (Figure 35A). If the line is not satisfactory, alternate lines are dialed and tested until a "go" line is found. That line is held, and the far-end receive line is dialed. This line is looped to the far-end transmit line, and the near end sends a tone through the loopback to the test instrument (Figure 35B). Alternately at this point a digital signal may be sent around and the modem itself used as the test device. Since the far-end transmit line is known to be good, only far-end receive lines need be dialed, until the loopback connection is good.

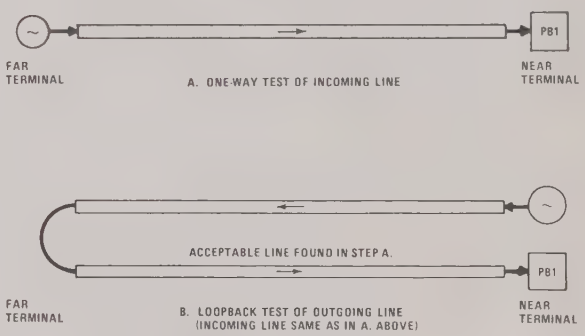


Figure 35 Evaluating Dual Dial Backup Lines

c. TRACKING NOTCH-FILTER FOR OTHER INSTRUMENTS

Since the instrumentation suppresses the steady-state component of received tone, leaving only the disturbances on that tone as 'notched noise' to be analyzed and displayed, it acts as an extremely narrowband notch filter. For example, the existing instrument can track any one of five input tones (404, 804, 1004, 1704, and 2804 Hz) over a ±8% frequency range. This notched noise is available as an electrical output for use by other instruments, as shown in Figure 36. This notched noise differs from the output of a conventional notch filter in that it is relative to a "normalized" test tone, and that phase relationships between the notched noise and the tone are not distorted. When fed to conventional noise meters, the notched noise output causes those meters to operate as notched noise meters. The same output permits impulse counters to operate on lines in the presence of holding tones without being triggered by those tones. The notched noise can also be fed to the vertical input of a cathode-ray oscilloscope for display of notched noise in the time domain. This permits estimation of the frequency of any predominant component of the notched noise. A useful display results if the external oscilloscope is used in an X-Y mode. The horizontal axis

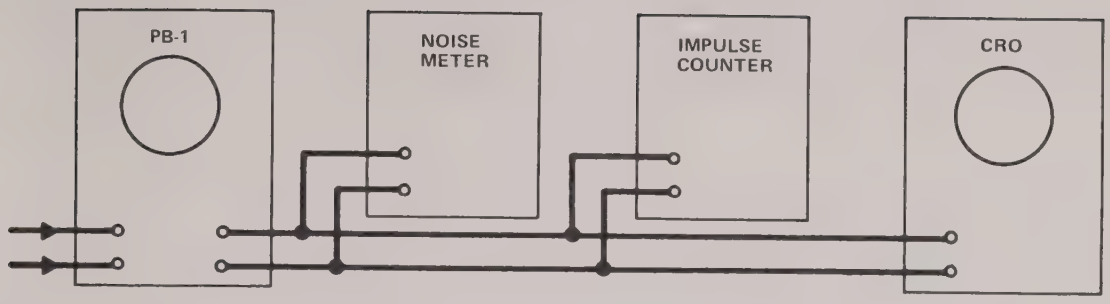


Figure 36 PB-1 VF Line Analyzer as a Tracking Notch Filter

is driven by the input signal (or by the PB-1 local oscillator as available at the rear connection) and the vertical axis is driven by the notched noise.

In the case of a normally noisy line, the noise components near the tone frequency cause continuous small errors in the tracking loops which results in a tone frequency component which is normally well below the background noise level inducing it. In the case of low frequency modulation impairments this effect is more pronounced.

d. CHECKING QUALITY OF TEST-TONE SOURCES

It is desirable to check station test-tone sources periodically. This is done by patching the instrument directly to the tone source and observing the source output with maximum sensitivity in the fundamental and harmonic modes. This assures that when a test-tone source is used for testing transmission channels, there are no disturbances (i.e., harmonics, level and/or frequenty shifts, phase and/or amplitude modulation, hum, noise, etc.) on the test tone what would be erroneously attributed to the transmission channels under test.

e. IDENTIFICATION OF FACILITIES BY SIGNATURES

The time constants of the AGC loop and of the Phase-Lock Loop are such that both loops operate rapidly enough to recover from transients within the 1/7 second dead-time interval of hit counters, but do not operate so rapidly that they mask hits, steps, or other transients. The hardware therefore responds to transients in ways that identify them acoustically. Gain or phase hits 'pull' the tracking loops, thus momentarily degrading the notch, causing a 'ping' as the tone 'leaks' through the recovery period. Low-frequency steady-state modulation also pulls the loops, causing a 'wow'. Impulse hits do not pull either tracking loop; they cause a 'pop'.

The visual and acoustic outputs frequently permit identification of telephone transmission facilities through which the test tone may pass. FDM, PCM, and Copper facilities have characteristic impairment; patterns which frequently permit identification.

Although there is no substitute for extended experience to develop facility identification capability, the following represent a starting point.

FDM (Figure 18)

Patterns in which phase jitter predominates usually indicate that FDM is involved. Low-frequency jitter is characteristic of older FDM's. Continuous small phase hits, visible and audible, order a magnitude a few degrees, are an indication the facility is passing through the heavy traffic area. Circular motion or high angular mobility of the harmonic distortion spot frequently indicates sync supply problems.

PCM (Figure 22)

Vertical excursion (amplitude jitter) exceeds horizontal, and harmonic distortion frequently is much larger than in FDM channels, particularly in older channel banks. VECTOR NOTCH pattern is sensitive to test tone frequency. Tone sources at 1000 Hz may result in aliasing products near 2 KHz and 3 KHz which moves the harmonic spot dramatically. Characteristic grinding sound. Excessive distortion and large radial steps in distortion spot may indicate timing or compandor problems.

Copper

No modulation impairments of any kind. Harmonic distortion may be present.

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MODEL 2A/2B LINE IMPAIRMENT GENERATOR

TRAINING

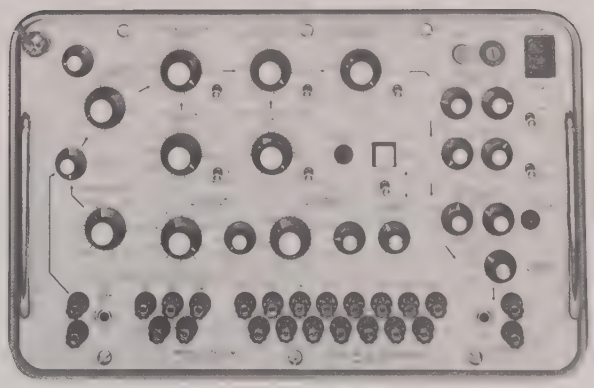
INSTRUMENT CALIBRATION

ANOMALY EXPLORATION OF INSTRUMENTS

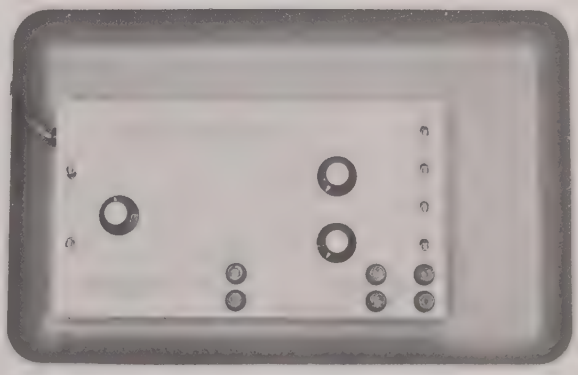
PERFORMANCE EVALUATION OF MODEM DESIGNS

PRODUCTION TESTING OF MODEMS

FACILITY IMPAIRMENT DIAGNOSTICS



Model 2A



Model 2B

The 2A/2B provides the most complete simulation capability for non-tariffed disturbances which exists. It is the only instrument which includes the following–

. . .amplitude jitter/gain phenomenon

. . .single frequency interference

. . .realistic hit capability (continuously variable rise time and duration)

. . .continuously variable jitter frequency

. . .internal tone oscillator

. . .impulse simulation repeatable from unit to unit

Because it was originally developed as an instrument calibrator the impairments are–

. . ."pure" or orthogonal, i.e., a phase hit does not include a gain hit

. . .continuously variable in all parameters

. . .accurately settable by calibrated panel dial

This unit is a complete, portable, single-box simulation facility. The range of variables is sufficiently large to include the full extent of possible variation. For example, when the 2A/2B was developed the low frequency jitter problem and the incidental AM problem had not been recognized, the dropout was defined differently, and the bewildering variety of hit profiles (which have become apparent in viewing facilities with the PB-1 Line Analyzer) was only suspected. Yet the 2A/2B simulates all of the above, including both the new and old dropout.

For facility impairment diagnostics the internal tone oscillator is used to simulate the test tone and the impairments are adjusted to provide results similar to those observed on the facility. This involves experimentally adjusting the amplitude and frequencies of steady state impairments, as well as the magnitude, duration, and rise time of transient phenomenon. In this connection the continuously variable controls are vital. After matching, the impairment characteristics are read from the panel dials. The most powerful application of this technique is achieved using a real time analog display such as the PB-1 in the phasor domain, to generate a similar time variable impairment as does the line, and thus comprehend the time history of transient events. Many "mysterious problems" have been solved by this technique.

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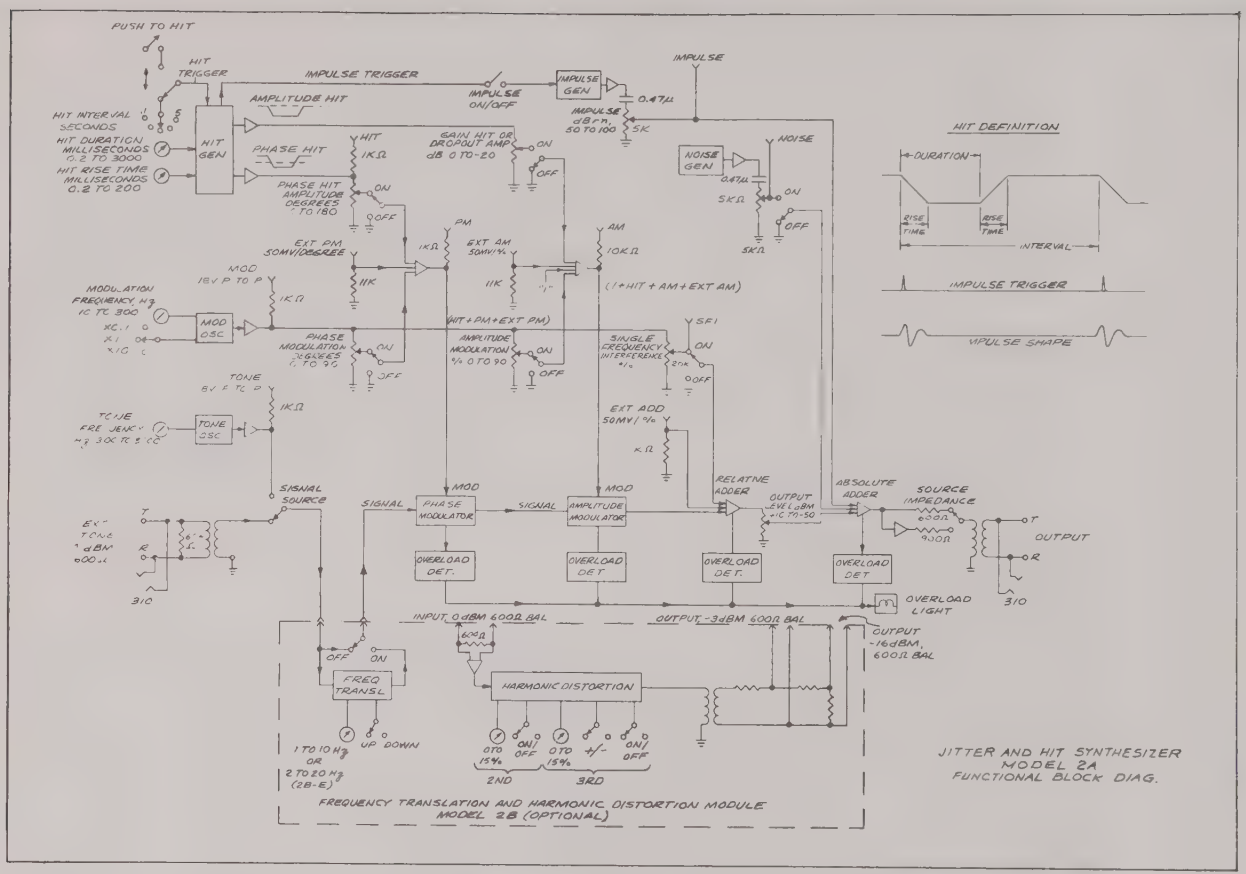
MODEL 2A/2B LINE IMPAIRMENT GENERATOR



Block Diagram of Data Line Synthesizer for Simulating Various Data Transmission Anomalies.

STEADY STATE IMPAIRMENTS

Voice band white noise — 0 to 50dBm
Frequency Translation — 1 to 10 Hz (or 2 to 20 Hz), up or down

Harmonic Distortion
- 2nd — 0 to 15%
- 3rd — 0 to ±15%

} These adjustments are independent of each other

Phase Jitter — 0 to 90°

Amplitude Jitter — 0 to 90%

Single frequency Interference — 0 to 90%

} The disturbance frequency may be varied from 1 to 3000Hz (internal oscillator) or may be controlled by external input signal.

HIT IMPAIRMENTS

Impulse Hits	+10 to -40dBm
Phase Hits	0 to 180°
Gain Hits	0 to 20dB
Dropouts	0 to 20dB
Frequency Hits	0 to 20Hz

} These hits have selectable or manually controlled occurrence rate, adjustable rise time — 0.2 to 200 milliseconds and adjustable duration 2 to 3000 milliseconds

The Model 2A Line Impairment Generator includes two variable frequency audio oscillators, a voice band calibrated noise generator, a voice band calibrated phase shifter, a trapezoidal pulse generator, and an impulse generator. All of these are independently useable as laboratory instruments. (See photo on reverse side)

Variations — The 2A/2B is available in rack mounting configuration 19" wide x 17½" high. It is also available in 100, 115 volt, and 230 volt 50/60 Hz versions.

2A-E 230V, 50/60 Hz
2A-J 100V, 50/60 Hz
2B-E 2 to 20 Hz Frequency Translation

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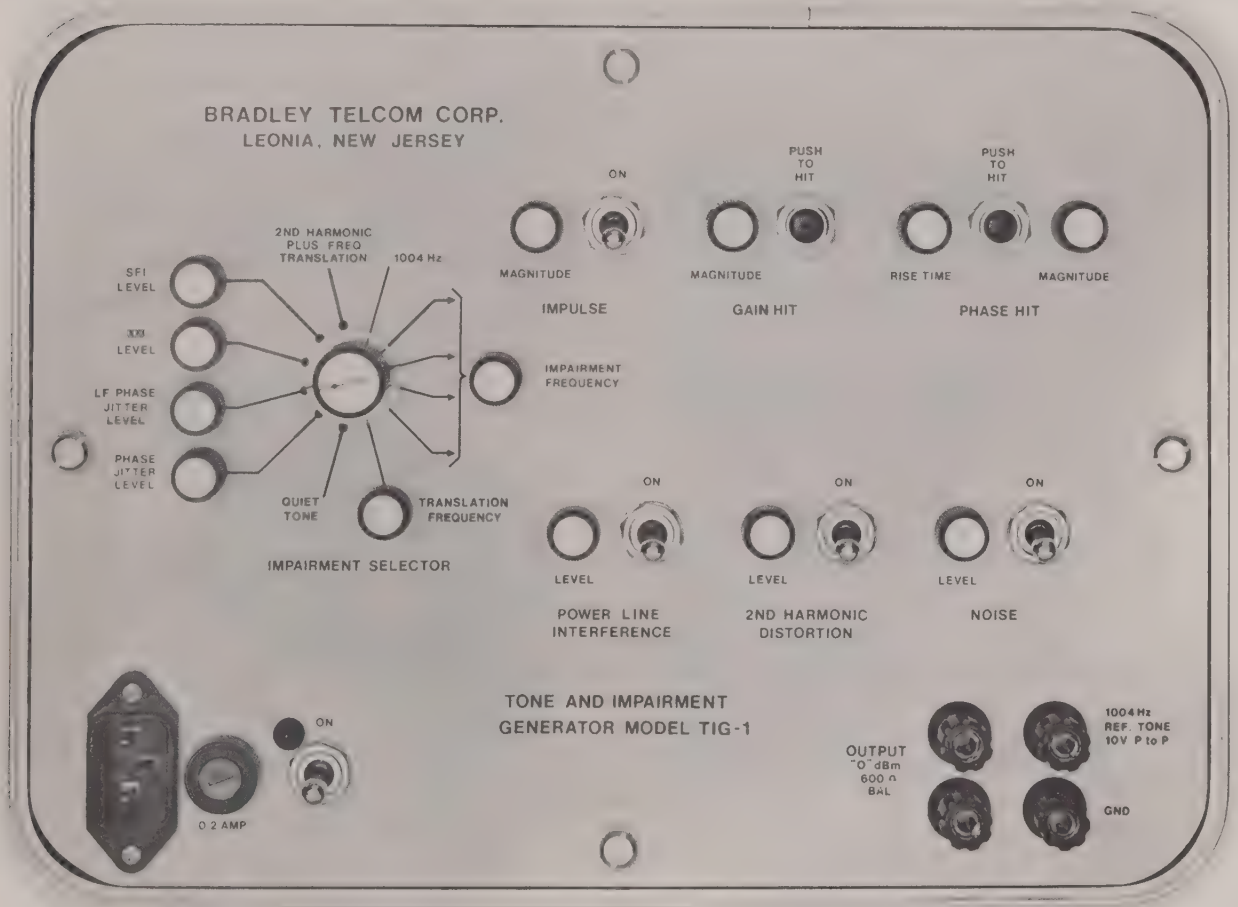
MODEL TIG-1 AND TIG-1E TONE AND IMPAIRMENT GENERATOR

FOR INSTRUCTED TRAINING
FOR CRAFTSMAN SELF-TRAINING

Demonstrate impairments
Demonstrate use of test equipment
Set up test problems

FOR ANALYSIS OF UNUSUAL IMPAIRMENT COMBINATIONS

Set up TIG-1 experimentally to match observed line characteristics



This "Trainer Box" unit realistically simulates a wide variety of line impairments. These are generated by methods similar to those employed in our 2A/2B Line Simulator. Significant economy is achieved by limiting operation to manipulation of an internally generated test tone only, and by providing impairments that are variable but not calibrated. The impairment ranges are chosen to be representative and the impairments may be mixed to achieve excellent simulation of FDM, PCM, and copper facilities. The unit is sufficiently low in cost that it may be justified as central office equipment for ongoing self or instructed training of craft.

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MODEL TIG-1 AND TIG-1E TONE AND IMPAIRMENT GENERATOR

FUNCTIONAL DESCRIPTION

The TIG-1 generates one of six selectable outputs as follows:

A. Pure 1004 Hz tone: 0 dBm at 600 ohms, dc blocked for 200 volts. All impairments more than 46 dB down.

B. Phase Modulation: 1004 Hz, 0 dBm tone with phase modulation adjustable from 5 to 15 degrees, 30 to 300 Hz.

C. Low-Frequency Phase Modulation: 1004 Hz, 0 dBm tone with phase modulation adjustable from 10 to 30 degrees, 0.5 to 5 Hz.

D. Amplitude Modulation: 1004 Hz, 0 dBm tone with amplitude modulation adjustable from 5 to 15%, 30 to 300 Hz.

E. Single-Frequency Interference: 1004 Hz, 0 dBm tone with SFI tone adjustable from -14 to -26 dB SFI tone at 240 to 2400 Hz.

F. Second Harmonic Distortion Followed by Frequency Translation: 1004 Hz, 0 dBm tone with nominally -30 dB 2nd harmonic distortion; translation frequency adjustable over at least ± 6 Hz.

The following impairments may be added to the output selected above, singly or in combination:

1. Gaussian Noise: Adjustable from -25 to -35 dBm.
2. Second Harmonic Distortion: adjustable from -25 to -40 dB.
3. Power Line Interference: adjustable from -14 to -26 dB.
4. Phase Hits: manually initiated and terminated, adjustable 5 to 25 degrees amplitude and 3 to 100 milliseconds transition time.
5. Gain Hits: manually initiated and terminated, adjustable 1 to 3 dB amplitude.
6. Impulse Hits: 2 per second, adjustable -5 to -15 dB.

PHYSICAL DESCRIPTION

The unit is packaged in a 9 x 12 x 4½" attache case with hinged cover, and with integral handle and latches. There is room within the case for line cord, test cords, and instruction book. The unit weighs 7 pounds.

POWER REQUIREMENT

TIG-1 90 to 125 volts, 50 to 60 Hz, 50 ma
TIG-1E 190 to 250 volts, 50 to 60 Hz, 25 ma

BRADLEY TELCOM CORP. ● 117 Fort Lee Road ● Leonia, New Jersey 07605 ● Telephone (201) 461-5903

TRANSPARENT LINE GENERATOR MODELS NNE 1000 AND NNE 1000R

WITH A SINGLE INEXPENSIVE TRANSPONDER

Extend Test Center Dynamic impairment measurement capability and diagnostic expertise to:

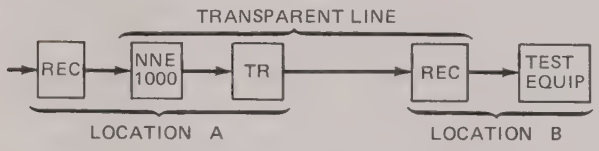
- Subscriber locations
- Less well-equipped C.O.'s
- Intermediate point VF appearances
- Back-to-back channel bank locations
- Unattended locations

Sectionalize Troubles at:

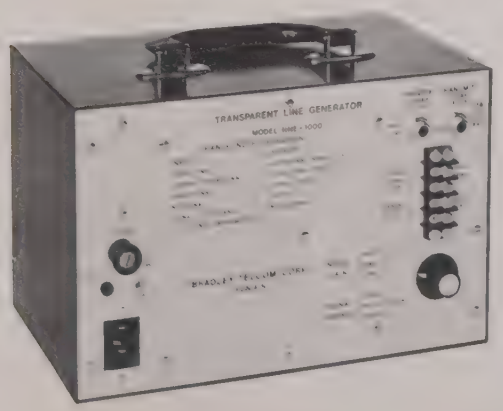
- Unattended microwave stations
- Multiple carrier interface
- Intermediate point VF appearances

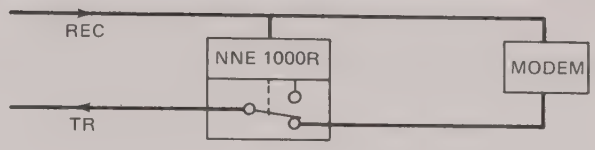
WHAT IT IS

Complete testing of a facility normally requires signal generating instruments, signal analyzing instruments, and maintenance personnel capable of interpreting results, at every terminal. The NNE unit permits the creation of a test loop in which one or more legs of the loop are made "transparent" thus requiring analyzing instruments and skilled personnel at only one location in a test loop. A facility which terminates at Location A may be tested from Location B with the connection between A and B becoming, in effect, a long test cord. The NNE is available in three versions designated NNE 1000, NNE 1000R, and NNE 1000 TTR.

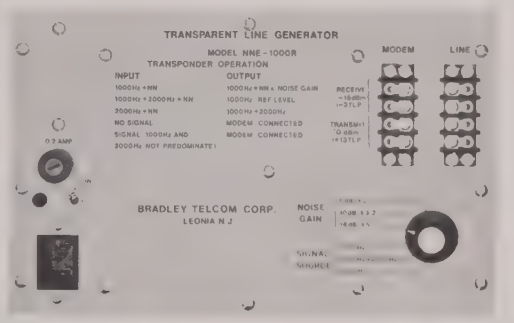


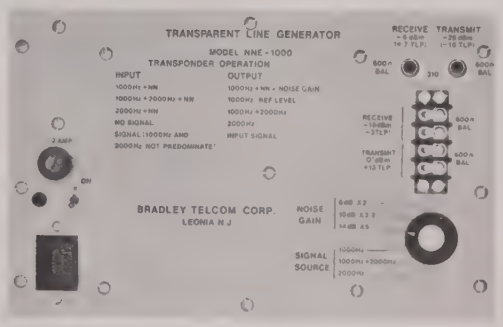
The NNE 1000 is a manually patched unit which accommodates either central office test levels (-6 dBm receive, -29 dB transmit) or subscriber site levels (-16 dBm receive, 0 dBm transmit), depending upon patching. Thereafter the operating modes of the unit are controlled via the signal path. Five modes are provided, as described below, to permit fully diagnostic operation for Loopback, Remote Point, and Third Point testing.



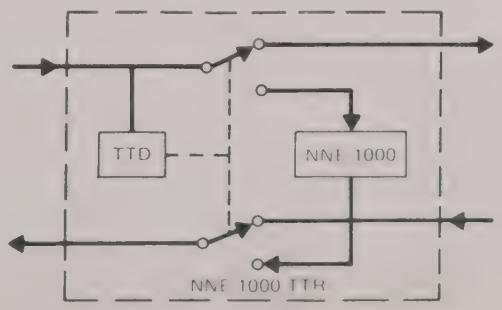


The NNE 1000R accommodates subscriber location levels (-16/0). It is automatically switched either by its own signal path to place a 4-wire line in a test mode, or via DDD to test a 2-wire line. In either case the NNE 1000R output is substituted for the normally connected equipment, see above, during that period when its input continuously receives signals in which 1000 Hz or 2000 Hz predominate.





The NNE 1000 TTR comprises a modified NNE 1000 with built-in specialized touch tone decoder (TTD). The TTD is controlled by a standard touch tone pair. The unit includes a four-pole double-throw transfer relay which latches in either position.



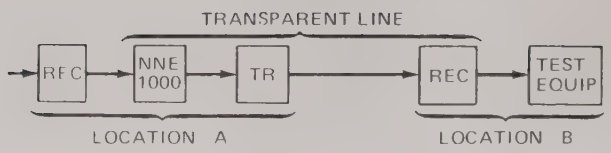
WHAT IT DOES

Line faults can be divided into two categories, those dynamic impairments which generate spurious noise, sidebands, or harmonics, in the presence of a test tone, and those impairments which characterize the steady state facility performance, i.e., gain vs frequency, envelope delay vs frequency, and return loss. The spurious signals generated by the dymanic impairments are all included in the quantity notched noise. It is these impairments for which the facility A to B above is rendered transparent by the NNE units. This includes:

Noise (Background, Quantizing, etc.)
Impulse Hits
Phase Jitter
Phase Hits
Amplitude Jitter
Gain Hits
Harmonic Distortion
Gain/Loss
Phase Intercept Distortion (Time Variation)
Frequency Translation
Single Frequency Interference

Impairments not included are the facility's basic linear properties, i.e., gain vs frequency, envelope delay vs frequency, and return loss. The NNE 1000 is itself transparent except for tones near 1000 Hz and 2000 Hz so that conventional looparound tests are possible (Mode 5 below).

Notched noise includes all disturbance components except for the tone, i.e., background noise, modulation products, harmonic products, and transient disturbances of all kinds. The NNE selectively amplifies the notched noise relative to the test tone by a known enhancement factor *without changing the phase relationship* between the tone and the



notched noise components, Mode 1 below. The notched noise enhancement factor, called "NOISE GAIN" is switch-selectable at 6 dB, 10 dB, or 14 dB. The signal launched at A is then so noisy as to make negligible the contribution of the notched noise introduction in the "transparent" facility. The measurements made at B are divided by the enhancement factor to establish their values at A.

In order to ensure that the transmission facility from A to B is not so poor as to invalidate the above assumption, Mode 2 below is provided. Mode 2 results in the NNE launching a pure tone at reference level into the return channel so that it can be checked for gain and dynamic impairments.

There is an overall gain or loss provided in the NNE units depending which input/output connections are used. In the NNE 1000 one set of connections (310 jacks) accepts -6 dBm nominal input and provides a -23 dB loss to the output for use at +7/-16 TLP's (central office). The other set (a 4-point barrier strip) accepts -16 dBm nominal input and provides 16 dB gain for use at -3/+13 TLP's (subscriber location).

The NNE 1000R provides two 4-point barrier strips, one for the line connection and the other for equipment connection. The receive level is nominally -16 dBm and the output level is +16 relative to the received signal.

OPERATING MODES

The operating modes are tabulated below:

MODE	INPUT	OUTPUT	OUTPUT LEVEL or INPUT-TO-OUTPUT GAIN	
			-3/+13 TLP (Barrier Strips)	+7/-16 TLP (310's)
1	1000 Hz + Notched Noise	Input + (Notched Noise) x (Noise Gain Factor). Relay transfers for NNE 1000R	(Rec Level +16 dB)	(Rec Level -23 dB)
2*	1000 Hz + 2000 Hz + Notched Noise	1004 Hz pure tone. Relay transfers for NNE 1000R	0 dBM	-29 dBm
3	2000 Hz + Notched Noise	1004 Hz pure tone + 2008 Hz Harmonic. Relay transfers for NNE 1000R	0 dBM	-29 dBm
4	No Signal (Signal Level 12 dB below nominal)	2008 Hz Tone, NNE 1000**	0 dBm	-29 dBm
		Received Signal, NNE 1000R	(Rec Level +16 dB)	(Rec Level -23 dB)
5	Any Signal within 12 dB of Nominal in which neither 1000 Hz or 2000 Hz predominate	Received Signal	(Rec Level +16 dB)	(Rec Level -23 dB)

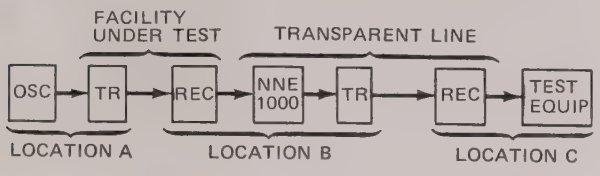
In addition to its "NOISE GAIN" position, the "MODE" switch has three "SIGNAL SOURCE" positions designated 1000 Hz, 1000+ 2000 Hz, and 2000 Hz. These are the control inputs for the first three transponder modes above. This permits an NNE unit to be used as a signal source to control remote NNE units; i.e., to be used as the oscillator in the block diagrams on the following pages.

* This command signal can be generated by another NNE or by the Bradley PB-O Oscillator, using the ADD HARMONIC switch of the oscillator.

** If a modem is playing through the NNE 1000, the appearance of a 2000 Hz indicates that the channel gain has dropped 12 dB below nominal.

REMOTE POINT TEST

Two-wire facility from A to B to be tested on location C.



CHECK TRANSPARENT LINE

1. Launch (1000 Hz + 2000 Hz) from oscillator. This establishes MODE 2 at NNE 1000, i.e., it transmits a pure 1004 Hz tone at reference level.
2. Transparent line is tested to make certain that it is a relatively normal line, and its 1000 Hz gain is measured.

CHECK FACILITY UNDER TEST

3. Launch 1000 Hz Tone from oscillator. This establishes MODE 1 at NNE 1000.
4. NNE 1000 returns tone at remote received level (adjusted for TLP) plus enhanced notch noise.
5. Remote receive level may be inferred from 1000 Hz gain calibration (2. above). Remote site received notch noise is determined by dividing local site readings by the "NOISE GAIN" setting.

STRAIGHT THROUGH CONNECTION

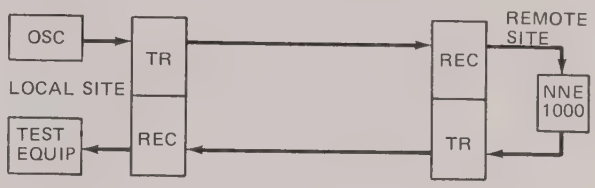
6. Transmit tone not within 5% of 1000 Hz or 2000 Hz, or complex signal in which 1000 Hz or 2000 Hz tones do not predominate. This establishes MODE 5 at NNE 1000 which then becomes transparent. The complex signal may include frequency "combs" of 10 or more equal amplitude tones which include 1000 Hz and 2000 Hz as elements of the comb.

SET-UP DIAGNOSTICS

7. Open circuit A to B — NNE 1000 detects "no signal" and assumes Mode 4. The 2000 Hz tone thus transmitted to C identifies the open circuit location.
8. Open circuit B to C — NNE 1000 generates an output in any of its modes. Thus if no signal is received at C, this indicates an open circuit in the link from B to C.

LOOPBACK TEST

Four-wire facility to be tested in each direction from a location at one end.



CHECK "REMOTE TO LOCAL" DIRECTION

1. Launch (1000 Hz + 2000 Hz) from oscillator. This establishes Mode 2 in the NNE 1000.
2. NNE 1000, in Mode 2, launches pure 1004 Hz tone at reference level toward local site.
3. Local receive line is tested and its 1000 Hz gain calibrated.

CHECK "LOCAL TO REMOTE" DIRECTION

4. Launch 1000 Hz from oscillator.
5. Remote site NNE 1000, in Mode 1, returns tone at remote received level (adjusted for TLP) plus enhanced notch noise.
6. Remote receive level may be inferred from 1000 Hz gain calibration (3. above). Remote site received parameters are determined by dividing local site readings by the "NOISE GAIN".

CONVENTIONAL LOOPBACK TEST

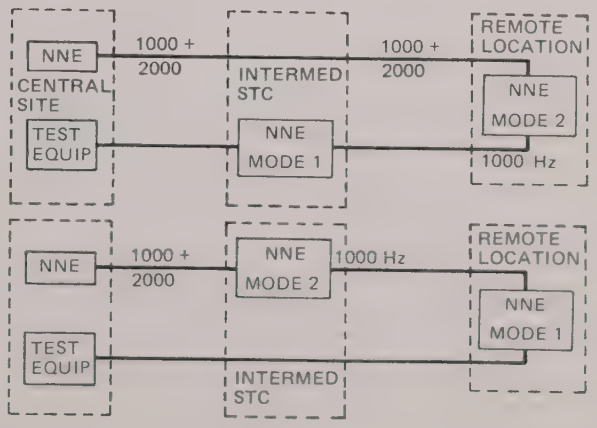
7. Transmit tone not within 5% of 1000 Hz or 2000 Hz, or complex signal in which 1000 Hz or 2000 Hz tones do not predominate. This establishes MODE 5 at NNE 1000 which then becomes transparent. The complex signal may include frequency "combs" of 10 or more tones which include 1000 Hz and 2000 Hz as elements of the comb.

SET-UP DIAGNOSTICS

8. Open circuit, local to remote — NNE 1000 detects "no signal" and assumes Mode 4. The 2000 Hz tone thus returned identifies the open circuit location.
9. Open circuit, remote to local — NNE 1000 generates an output in any of its modes. Thus if no signal is received at the local site, this indicates an open circuit in the return path.

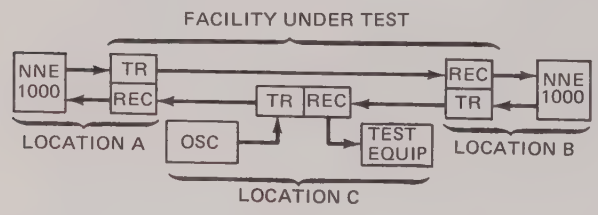
TESTING VIA AN INTERMEDIATE STC

Refer to figure, testing via an intermediate STC can be accomplished using a single NNE 1000 at the STC and either an NNE 1000 or an NNE 1000R at the remote terminal. The NNE transpondor at the STC is manually shifted between the transmit and receive side.



THIRD POINT TEST

Two-wire facility from A to B to be tested from location C. Tests to be fully controlled from C.



CHECK FACILITY "B TO C"

1. Launch 2000 Hz C toward A. This places NNE 1000 at A in Mode 3.
2. Location A transmits 1000 + 2000 Hz tone. This places NNE 1000 at B in Mode 2.
3. Location B transmits pure 1004 Hz tone at reference level toward C.
4. Test equipment at C is used to make certain that line is relatively normal, and its 1000 Hz gain is measured.

CHECK FACILITY "A TO B"

5. Launch 1000 Hz + 2000 Hz C toward A. This establishes NNE 1000 at B in MODE 2.
6. Location A transmits pure 1004 Hz tone at reference level toward B.
7. NNE 1000 at B, in Mode 1, sends tone at received level (adjusted for TLP) plus enhanced notch noise toward C.
8. Received level at B may be inferred from 1000 Hz gain calibration (4. above). Location B received parameters are determined by dividing location C readings by "NOISE GAIN" setting.

CONVENTIONAL LOOPAROUND TEST

9. Transmit tone not within 5% of 1000 Hz or 2000 Hz, or complex signal in which 1000 Hz or 2000 Hz tones do not predominate. This establishes MODE 5 at NNE 1000 which then becomes transparent. The complex signal may include frequency "combs" of 10 or more tones which include 1000 Hz and 2000 Hz as elements of the comb.

SET-UP DIAGNOSTICS

10. Open circuit C to A — NNE 1000 at A is placed in MODE 4. NNE 1000 at B is thereby placed in MODE 2. Location C receives 1000 Hz + 2000 Hz indicating open circuit C to A.
11. Open circuit A to B — NNE 1000 at B is placed in MODE 4. Location C receives 2000 Hz indicating open circuit A to B.
12. Open circuit B to C — Absence of signal at C indicates open circuit B to C.

SPECIFICATIONS NNE 1000

As transponder

Input - 600Ω, Balanced, dc blocked for 200 volts, either - 16 + 6/-12 dBm or -6 + 6/-12 dBm

Output - 600Ω, Balanced, dc blocked for 200 volts +16 or -23 dB relative to input for Mode 1 and Mode 5, 0 dBm or -29 dBm for Modes 2, 3, and 4

"NOISE GAIN" - Applicable to Mode 1, NNE 1000 mode switch selectable at +6 dB, +10 dB or +14 dB "NOISE GAIN"

CONTROL

Mode 1 initiated by - 1010 Hz ± 20 Hz not more than 2 dB below average received level.

Mode 2 initiated by - 1010 Hz ± 20 Hz not more than 2 dB below average received level plus 2020 Hz ± 40 Hz. The transition to Mode 2 occurs when the level of second harmonic exceeds -20 dB relative to the 1000 Hz fundamental.

Mode 3 initiated by -20 Hz ± 40 Hz not more than 2 dB below average received level.

Mode 4 initiated by - received level more than 12 dB below nominal received level.

Mode 5 initiated by - received level within 12 dB of nominal and no 1010 ± 20 Hz or 20 ± 40 Hz component greater than -10 dB relative to received level.

Switching activation requires at least 2 seconds of command tone to cause a transition. Removal of the command tone will cause reversion to Mode 4 or 5 two seconds after that tone is removed.

As Signal Source

Output - 600Ω, Balanced, dc blocked for 200 volts, 0 dBm

"SIGNAL SOURCE" positions of NNE 1000 "mode" switch selects output tone or tones of 1000 Hz, 1000 Hz + 2000 Hz, or 2000 Hz.

1000 Hz tone - all impairments (phase jitter, amplitude jitter, harmonic distortion, hum) - individually - 60 dB relative to tone.

1000 Hz tone - as above plus 2000 Hz 2nd Harmonic 16 dB below tone.

2000 Hz tone - at 0 dBm or -29 dBm.

SPECIFICATIONS NNE 1000R

As above, except that subscriber location levels only are accommodated, i.e., -16 dBm nominal receive and 0 dBm nominal transmit level, and the input impedance is bridging. Two 4-point barrier strips are provided, one for the line side connection and one for the drop (modem) side. The NNE 1000R is bridged across the line when the receive signal is of the form required to induce Modes 1 through 3 above, a two-pole transfer relay is activated. This is internally wired to remove the connection between the drop side transmit and the line, replacing this connection with the transmit side of the NNE 1000R. The NNE is then in one of its three modes.

APPLICATIONS

NNE 1000

SUBSCRIBER LOCATION LOOPBACK (SEE LOOPBACK TEST ABOVE)

Conventional testing of a loopback-connected four-wire line results in measurement of the instantaneous sum of the impairment contribution in each path. Some impairments may cancel, others may add linearly, others may add on a power (rms) basis. It is thus desirable to test each path separately: conventional loopback testing is only an expedient. To test each path one way using the NNE, the modem is unplugged from the four-wire line and replaced by the NNE 1000. The full technical expertise and test equipment complement of a central location can then be applied to each path. The field operation consists of replacing one plug with another. This is sufficiently simple so that the unit could be left in site and patched in when an intermittent problem occurs. The NNE 1000R permits this patching to be accomplished automatically.

CENTRALIZED MONITORING USING EXISTING DEDICATED FACILITY (SEE REMOTE POINT TEST ABOVE)

It is desirable to centralize facility testing so that high performance instrumentation and high level expertise can be multiplied in effectiveness. This has lead to systems which involve compensated dedicated test lines to reach a multiplicity of remote test nodes. Several of these systems exist in which a frequency comb is used. Such systems essentially calibrate out the steady state characteristics of test lines, and these lines are permanently assigned to the test function. The NNE 1000 is transparent to frequency combs and hence can be placed permanently in tandem with the transponder. It renders the test line effectively transparent to all those impairments which are not compensated for by the comb technique, i.e., all the components of notched noise. It is thus possible to achieve a large performance increment in an already installed access arrangement by adding a relatively inexpensive NNE 1000 at each remote site, plus one for control at the central site. Remote trouble lines can be routed to a single central location for rapid diagnostics with the PB-1 or for a slower and less complete analysis by conventional test equipment.

Only one set of such central test equipment is required to service the whole system.

CENTRALIZED TESTING, DDD OR PATCHED ACCESS

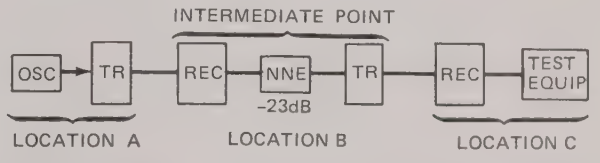
The nature of the NNE 1000 is such that it need not permanently be associated with a dedicated test line. Thus the same functions as above can be accomplished without resorting to an existing access arrangement and dedicated lines. Either the DDD network or patched lines can be used for this purpose. Again, all of the sophisticated diagnostics can be carried out by a single highly trained crew using a single high performance instrumentation set-up.

SECTIONALIZATION AT A REMOTE UNATTENDED SITE

For inaccessible locations such as may be found on multihop baseband radio systems an NNE 1000, with associated crystal oscillator, brings a pilot down to VF. VF access from a central location is provided to the NNE output so that the site can be monitored without physically going there.

INTERMEDIATE POINT VF APPEARANCE

Certain data problems are not well delineated by conventional carrier test equipment and certain VF appearances occur in what are essentially carrier equipped offices. At these intermediate point VF appearances, which are provided to permit transitions between carrier systems, the channel is routed in and out via a 23 dB pad. To permit sectionalization at such offices without trained VF personnel and without extensive VF test equipment an NNE 1000 is patched in place of the 23 dB pad. Testing and sectionalizing for dynamic impairments can then be accomplished in the facility ahead of and the facility behind the intermediate point with no further attention from intermediate point personnel and no further requirement for intermediate point VF test equipment.



1. Send 1004 Hz to check facility from A to B, i.e., NNE in Mode 1.
2. Send 1000 Hz + 2000 Hz to check facility from B to C, i.e., NNE in Mode 2.

NNE 1000R

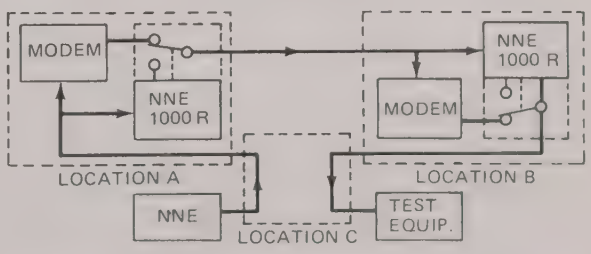
AUTOMATIC TESTING AT SUBSCRIBER LOCATION, UNATTENDED

The NNE is transparent to synchronous modem data streams. It is controlled by, and generates controlled outputs in the presence of, 1000 Hz or 2000 Hz predominant input signals.

The NNE 1000R is aimed at detection of intermittent troubles, or for use at unusually inaccessible sites. The unit is bridged on the input lines, as shown on the first page. An integral relay transfers the output line from the modem to the NNE 1000R when the appropriate command tones are present on the receive line. It is thus possible to test the path to, and the path from the remote modem, using the 4-wire line for signaling. This is accomplished without patching or any other operator intervention at the modem site.

All of the operating modes (see table) described above continue to function, permitting the full range of control.

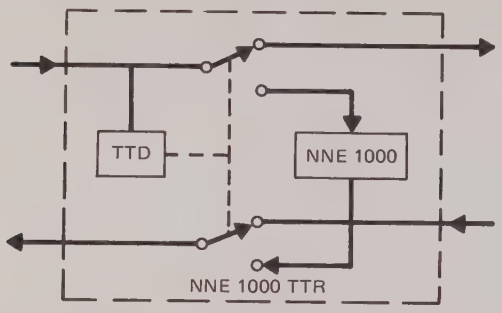
The most general case is shown below.



Alternately a DDD accessed 4 PDT relay may be used to switch the modem "out" and the NNE 1000 "in" for test purposes. A touch tone addressable version of the NNE 1000, with 4-pole latching relay, is described below. This unit is designated NNE 1000TTR: It is useful in sectionalizing impairments in multipoint and in tandem facilities.

FUNCTIONAL DESCRIPTION

The NNE 1000–TTR comprises a modified NNE 1000 with a built-in specialized touch tone decoder (TTD). The TTD is controlled by standard touch tone pairs. The unit includes a four-pole double-throw transfer relay which latches in either position.



The TTD section is bridged across the receive side VF line. It recognizes a designated touch tone code (2 out of 8) as a set up command and latches a four-pole form C reed relay in its energized position. It recognizes a second designated touch tone code as a release command and unlatches the four-pole relay, returning it to its de-energized position. The switching transition time is nominally 1/2 second in either direction. The unlatch command is pre-emptive, i.e., in the simultaneous presence of the set up command and the release command, the relay resides in, or returns to, its de-energized position.

The NNE–TTR may be used to extend NNE capability to multipoint data circuits, it may be used for remote sectionalization of faults in tandem radio facilities, or it may be used as a noise-immune remotely controllable switch for placing a remote facility in either an NNE test mode or in normal operation. The noise immunity arises from the fact that at least two tones must be present and at least one tone must not be present to cause transfer to the "test" mode.

The NNE section is an NNE 1000 modified as follows:

1. The NOISE GAIN/SIGNAL SOURCE switch is removed.
2. Input and output connections are made via four four-point barrier strips.
3. The NOISE GAIN is internally selectable at 6, 10, or 14 dB, rather than panel selectable.
4. The "SIGNAL SOURCE" capability is eliminated.
5. Nominal input and output levels and terminating impedances are to be specified by the customer.

The set up command is designated as one of 15 unique tone pair combinations at the time of manufacture. The release command is common to all TTD units and is the touch tone code for the * key.

SYSTEM OPERATION

The representative system diagram shows a three point tandem facility which might comprise, for example, the VF appearances of a dedicated four-wire test channel which is monitored for purposes of sectionalizing problems on a radio system. The TTD relays are shown in their de-energized position for the first and last terminal and in their energized position for the center terminal. When any TTD re-relay is energized, the path is looped via the NNE 1000 at that point.

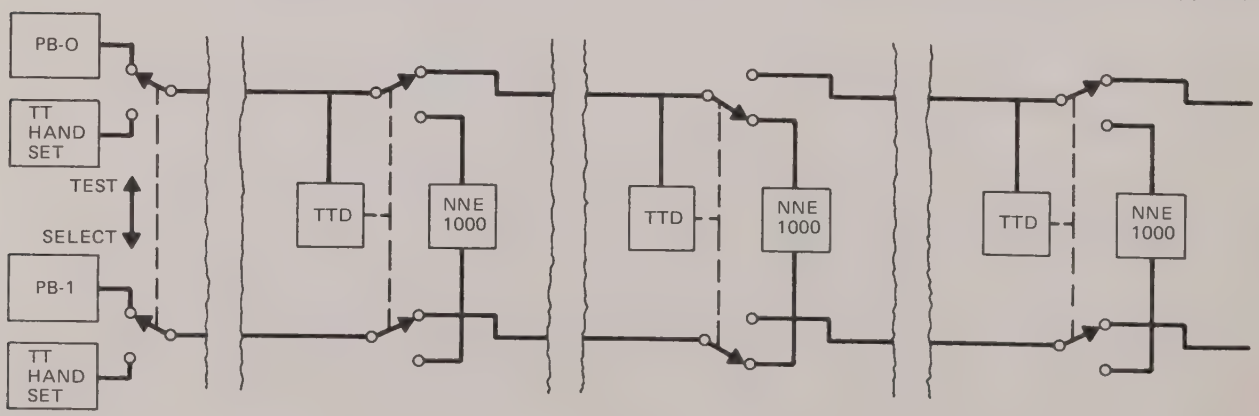
The representation is functional only, the NNE operates at the correct TLP's and impedances as specified by the customer. The straight-through connection, i.e., relay unenergized, must also be correctly matched. This latter matching is the customer's responsibility.

System control is via a touch tone send handset and a receive handset. Set up is verified by listening to the receive handset while manipulating the send handset keys as described below. The handsets, the TEST/SELECT switching, and control line access are provided by the customer.

Loopback at a specific location is established by

1. Placing the TEST/SELECT switch in a select position.
2. Sending the release code, *, while listening to the receive handset. If a loopback had been established at some location the receive handset will hear the release tone code momentarily, until the loop is dropped, after which there will be silence. A silent period of 1 second or more in duration will indicate that any loopbacks have been dropped.
3. Send the set up code for the desired looping point. After the set up delay, the receive handset will hear the set up tone code. A loopback connection has then then been established.

Thereafter testing may be accomplished using the NNE 1000 to separately examine the transmit and receive side of the facility from the central location to the designated loopback point. Sectionalization is accomplished by successively looping back at the remote locations in sequence and noticing when an impairment appears (or disappears).



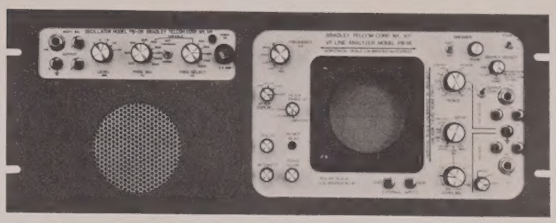
TEST EQUIPMENT

Many of the component impairments of notched noise listed on the second page are measured by conventional transmission measuring equipment, any of which may be used as the "TEST EQUIPMENT" referred to in the various block diagrams. The Bradley PB-1 measures all of the impairments listed and it is scaled in such a way that, in most cases, two steps on the range switch correspond to 5 to 1 (14 dB) ratio, one of the NOISE GAIN values. The PB-1 and PB-0 are described below.

THE MODEL PB-1 VOICE-FREQUENCY LINE ANALYZER IS A COMPACT, LIGHTWEIGHT, PORTABLE INSTRUMENT WHICH:

- Detects all disturbances, including types ignored by other instruments
- Provides comprehensive diagnostic capability
- Makes Go/No-Go evaluation of lines, using voice or data criteria

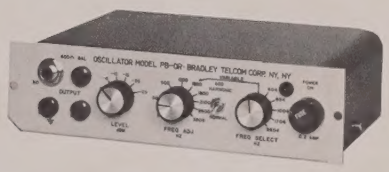
PB-1R – Rack Mounting VF Line Analyzer



Options available with either PB-1 or PB-1R

Hold coil option – 180 ohm hold coil, 2 Hy at 60 milliamperes. Switchable IN or OUT. Add $100.

Sixth frequency – A sixth operating frequency, between 300 and 3,000 Hz, may be designated by the customer. Add $100.



PB-OR

PB-O

The PB-O and PB-OR are station-quality oscillators despite their small size. They exhibit 1 Hz frequency accuracy, 0.2 dB level accuracy. Individual impairments in the output tone are in the -60 dB range. This is 20 dB below the normal "best telecommunication facility" which is to be examined using the oscillator as a test tone.

Frequency is either variable or switch selectable to those frequencies required for Bell System and CCITT gain slope measurements. These operating frequencies are the same for the PB-1 Line Analyzer. The output is switch selectable at six levels to accommodate the common Test Level Points.

The PB-O series oscillators also include an "ADD HARMONIC" mode in which -20 dB of second harmonic may be deliberately introduced. This feature permits examination of facilities for both frequency translation and for "Time Varying Phase Intercept Distortion" (See PB-1 data sheet), and for control of NNE-1000.

ORDERING INFO

Three functional variations of the NNE are available, as follows:

NNE 1000
NNE 1000R
NNE 1000 TTR

Also available is a transit case. The outside dimensions of this case are 7 1/4 x 8 1/4 x 12 3/4". It includes two cord pockets and is held closed by a strap rather than latches for shipping integrity.

Order – Transit case NNE

Other frequencies – The NNE units are avilable in an 800 Hz version in which case the "1000" in the designation becomes "800", i.e.,

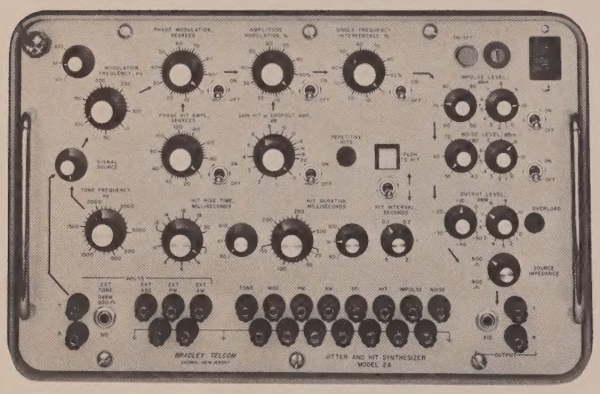
NNE 800
NNE 800R
NNE 800 TTR

Power line voltage

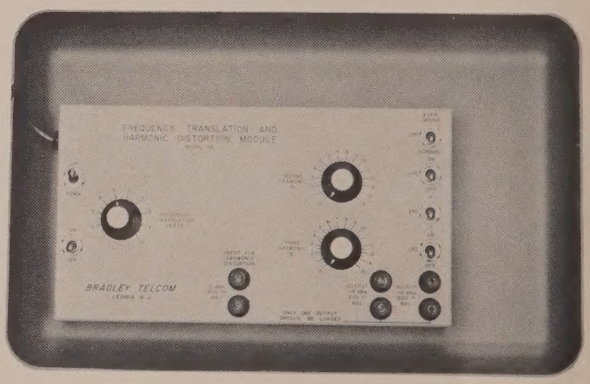
The standard unit operates at 50/60 Hz, 115 volts. For 230V 50/60 Hz operation, add E to designation. For 100 V 50/60 Hz, J. For example:

NNE 1000E	or	NNE 800E
NNE 1000RE		NNE 800RE
NNE 1000 TTRE		NNE 800 TTRE

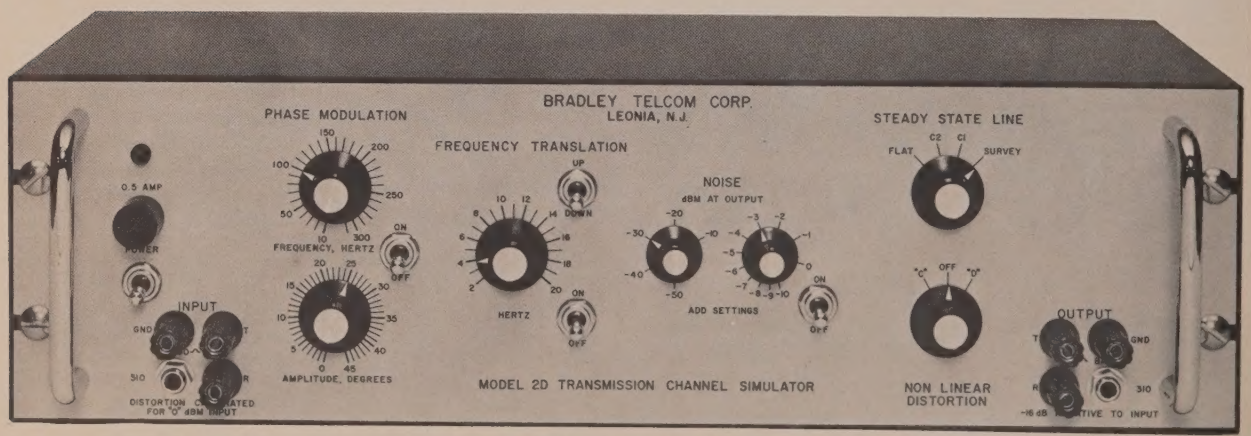
BRADLEY TELCOM ALSO MANUFACTURES LINE SIMULATORS, SEE BELOW



Model 2A Jitter and Hit Synthesizer

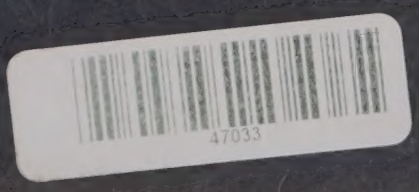


Model 2B Frequency Translation and Harmonic Distortion Module



Model 2D Modem Production Tester

DUO-TANK
5125S
MADE IN U.S.A.



DUO-TANG®
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